GEOTECHNICAL INVESTIGATION
SURFACE WATER TRANSMISSION PROGRAM
84-INCH INTERCONNECTION
WBS NO. S-000902-0132-4/
LOW LIFT PUMP STATION (LLPS)
DIRECT CONNECTION AND
PRESSURE REGULATING STATION (PRS)
WBS NO. S-000902-0133-4
AT EAST WATER PURIFICATION PLANT (EWPP)
HOUSTON, TEXAS

REPORT NO. 1140193801

Reported to:

LOCKWOOD ANDREWS & NEWNAM, INC.

Houston, Texas

Submitted by:

GEOTEST ENGINEERING, INC.

Houston, Texas

Key Map Nos. 496 U & Y

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Report No. 1140193801
May 14, 2014

Mr. Will Wilshire, P.E.
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Houston, Texas 77042

Reference: **Geotechnical Investigation**
Surface Water Transmission Program
84-Inch Interconnection
WBS No. S-000902-0132-4/
Low Lift Pump Station (LLPS)
Direct Connection and Pressure Regulating Station (PRS)
WBS No. S-000902-0133-4
At East Water Purification Plant (EWPP)
Houston, Texas

Dear Mr. Wilshire:

Presented herein is the geotechnical investigation final report for the above referenced project. Preliminary boring logs were submitted to LAN on December 12, 2013. Design soil parameters for the vaults were provided to you on January 8, 2014. Draft report was submitted to you on January 28, 2014. Axial capacity curves for 30-inch diameter drilled shaft for pipe support were submitted to you on April 8, 2014. This final report will supersede the previously submitted reports, transmittals, e-mails, etc. for the referenced project. This study was authorized by Task Order 978/2 on March 15, 2013 by accepting our Proposal No. 1140327399, dated February 1, 2013 and Notice to Proceed with revised exhibit on October 23, 2013 and e-mail authorization for additional boring near bayou at EWPP on January 7, 2014.

We appreciate this opportunity to be of service to you. Please call on us when we can be of further assistance to you.

Very truly yours,
GEOTEST ENGINEERING, INC.
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EXECUTIVE SUMMARY

A geotechnical investigation was conducted in connection with the design and construction of 84-inch, 60-inch, 48-inch and 42-inch waterlines, pressure regulating stations and control buildings to have a direct connection between existing 60-inch Raw Water Line at Plant 1 and 2, existing 84-inch Raw Water Line at Plant 3 and Low Lift Pump Stations (LLPS) at Plant 1 and 2 at East Water Treatment Plant. The proposed water line is generally constructed by open cut method except at the crossings of Hunting Bayou and Pipelines, where tunneling is proposed.

This investigation included drilling and sampling seven (7) soil borings to depths ranging from 25 to 50 feet, performing laboratory tests on soil samples recovered from the borings, performing engineering analyses and preparing a geotechnical report.

The principal findings and conclusions developed from this investigation are summarized below:

- Based on review of Harris-Galveston coastal subsidence district maps, it was noted that subsidence in the Houston area has substantially decreased in recent years. During 1906 through 2000, subsidence in the project area appears to have been between 7 and 8 feet. During 1978 through 2000, subsidence in the project area appears to have been between 0.5 and 1 feet. During 1995 through 2010, subsidence in the project area appears to have been between 0 and 0.25 feet.

- Based on the review of the available information, the nearest known surface fault is of faults associated with Clinton Salt Dome which is approximately 1,000 feet north of the project alignment. The available information consisted of U. S. Geological Survey maps, open file reports, and information contained in our files relating to geologic faults in the area.

- The subsurface conditions for proposed 84-inch Interconnection/Low Lift Pump Station Direct Connection and Pressure Regulating Station at EWPP are summarized below:

As revealed by boring logs GLLP-1 through GLLP-7, the subsurface soil below the existing grade consists of soft to hard brown, gray, yellowish brown and reddish brown Fat Clay, Lean Clay, Fat Clay w/sand, Lean Clay w/sand and Sandy Lean Clay to a depth of 25 feet, the explored depth in borings GLLP-3 through GLLP-7 and to a depth of 40 feet in boring GLLP-2. In boring GLLP-1, a stratum of medium dense gray Silty Sand was encountered between depths of 9.5 to 12 feet and very dense reddish brown Sandy Silt was encountered below 36 feet to the explored depth of 50 feet. In boring GLLP-2, the clays are underlain by dense to very dense reddish brown Silt to explored depth of 50 feet. A stratum of reddish brown Clayey Silt was encountered between the depths of 10 and 12 feet in boring GLLP-7. In borings GLLP-2, GLLP-4, GLLP-5 and GLLP-7, fill material consisting of medium stiff to very stiff brown, yellowish brown, gray and reddish brown Fat Clay, Fat Clay w/sand and Lean Clay w/sand, grass roots, calcareous and ferrous nodules was encountered to a depth of 6 and 10 feet below the existing grade.

- The groundwater was encountered at depths ranging from 10 feet to 23 feet in all the borings GLLP-1 through GLLP-7 during drilling. The water level measured 20 minutes after water was first encountered is at depths ranging from 4.8 to 9.4 feet in these borings. The groundwater as observed on December 5, 2013 in Piezometer GLLP-5P is at depth of 4.2 feet. The ground water as observed on December 27, 2013 in piezometers GLLP-3P and GLLP-7P is at depths of 9.2 and 3.7 feet, respectively.

- All excavations and trenching operations should be in accordance with OSHA standards.

- Bedding and backfill for the 60-inch water line extension, 42-inch and 48-inch water lines and 84-inch Water Line Interconnect should be in accordance with the City of Houston Standard Specification Section 02511 “Water Lines” and Drawing No. 02317-04.

- Geotechnical parameters for design of restrained joints, tunneling and structures are provided in Section 5.0 of this report.

1.0 INTRODUCTION

1.1 General

Lockwood Andrews & Newnam, Inc. (LAN) was selected by City of Houston to provide engineering design construction program management services in support of Surface Water Transmission Program (SWTP). LAN then selected Geotest Engineering, Inc. to provide geotechnical engineering services related to the design and construction of Low Lift Pump Station Direct Connection and Pressure Regulating Station at EWPP.

1.2 Location and Description of the Project

A geotechnical investigation was conducted in connection with the design and construction of 84-inch, 60-inch, 48-inch and 42-inch waterlines, pressure regulating stations and control buildings to have a direct connection between existing 60-inch Raw Water Line at Plant 1 and 2, existing 84-inch Raw Water Line at Plant 3 and Low Lift Pump Stations (LLPS) at Plant 1 and 2 at East Water Treatment Plant. The proposed water line is generally constructed by open cut method except at the crossing of Hunting Bayou and Pipelines, where tunneling is proposed.

The vicinity map is shown on Figure 1.

1.3 Scope of Work

The purposes of this investigation were to determine the subsurface conditions and to develop geotechnical recommendations for the design and construction of the proposed 84-inch Interconnection/Low Lift Pump Station Direct Connection and Pressure Regulating Station at EWPP. The scope of this investigation was based on the information furnished by LAN and consisted of the following tasks.

- Drilling and sampling (intermittent and continuous) of seven (7) borings and installing three (3) piezometers in existing borings. The continuous sampling was performed from 0 to 20 feet and in the tunneling zone. The tunneling zone includes one bore diameter or minimum 6 feet above the pipe crown to one bore diameter or minimum 6 feet below the pipe invert. The intermittent sampling was performed at 5-foot intervals in the remainder depths of borings.

- Performing appropriate laboratory tests on selected samples to develop engineering properties of the soil.

- Performing engineering analyses to develop geotechnical recommendations for the design and construction of the 42-inch, 48-inch, 60-inch and 84-inch water line, low lift pump station, pressure regulation station, vaults and building. The recommendations will include net allowable bearing capacity, at rest and active equivalent fluid density of lateral soil pressures acting on exterior underground walls, coefficient of sliding friction, vertical modulus of subgrade reaction, buoyant uplift factor of safety, shallow foundation slab on grade design, pipe support and construction considerations.

- Preparing a geotechnical report in accordance with City of Houston Guidelines and the SWTP Manual. The report includes all field data, laboratory test data and geotechnical recommendations.

2.0 SUBSURFACE INVESTIGATION PROGRAM

2.1 Geotechnical Borings

Subsurface conditions were explored by drilling and sampling seven (7) soil borings, designated as GLLP-1 through GLLP-7, to depths ranging from 25 to 50 feet. The borings were marked in the field by Geotest representative based on the drawings provided to us by LAN. **Hard obstruction was encountered at 2 feet in boring GLLP-6** and the boring was offset to GLLP-6A and drilled to the explored depth of 25 feet. All the borings were drilled with a truck mounted drilling rig. The approximate locations of all these borings are shown on Figure 2, Plan of Borings. The survey information (Northing and Easting coordinates and ground surface elevation) of the completed borings were provided to us by LAN. A summary of subsurface investigation program is provided in Table 1.

Samples were obtained continuously to a 20-foot depth and at 5-foot intervals thereafter in borings GLLP-3 through GLLP-7. In borings GLLP-1 and GLLP-2 drilled at tunnel location at Hunting Bayou crossing, samples were obtained continuously to a 42-foot depth and at 5-foot intervals in the remainder depth of boring. In general, samples of cohesive soils were obtained with a 3-inch thin-walled tube sampler in general accordance with ASTM Method D 1587 and cohesionless soils were sampled with a 2-inch split-barrel sampler in accordance with ASTM Method D1586. Each sample was removed from the sampler in the field, carefully examined, and then logged by an experienced soils technician. Suitable portions of each sample were sealed and packaged for transportation to Geotest's laboratory. The shear strength of cohesive soil samples was estimated using a pocket penetrometer in the field. Driving resistances for the split-barrel samples were recorded as "Blows per Foot" on the boring logs. All borings were grouted with cement bentonite grout after completion of drilling and obtaining water level measurements with the exception of borings GLLP-3, GLLP-5 and GLLP-7 which were converted to piezometer.

Detailed descriptions of the soils encountered in the borings are given on the boring logs presented on Figures A-1 through A-7 in Appendix A. A key to "Symbols and Terms used on Boring Logs" is given on Figure A-8 in Appendix A.

2.2 Piezometer Installation

During the field investigation, a piezometer was installed in the open bore hole of borings GLLP-3, GLLP-5 and GLLP-7. The location of the piezometers, designated as GLLP-3P, GLLP-5P and GLLP-7P, are shown on Figure 2. Piezometer installation record showing details of the construction of piezometers are provided on Figures C-1 through C-3 in Appendix C.

After taking final water level measurements, the piezometers were abandoned in place. The piezometers abandonment reports are presented in Appendix E.

3.0 LABORATORY TESTING PROGRAM

The laboratory testing program was designed to evaluate the pertinent physical properties and shear strength characteristics of the subsurface soils. Classification tests were performed on selected samples to aid in soil classification. All the tests were performed in accordance with appropriate ASTM procedures.

Undrained shear strengths of selected cohesive samples were measured by unconsolidated undrained (UU) triaxial compression (ASTM D2850) tests. The results of UU triaxial compression tests are plotted on the boring logs as solid squares. The shear strength of cohesive samples was measured in the field with a calibrated hand pocket penetrometer and also in the laboratory with a Torvane. The shear strength values obtained from the penetrometer and Torvane are plotted on the boring logs as open circles and triangles, respectively.

Measurements of moisture content and dry unit weight were taken for each UU triaxial compression test sample. Moisture content measurements (ASTM D2216) were also made on other samples to define the moisture profile at each boring location. The liquid and plastic limit tests (ASTM D4318) were performed on appropriate samples. Sieve analysis (ASTM D422) and percent passing No. 200 sieve (ASTM D1140) tests were performed on selected samples. The results of all tests are plotted or summarized on the boring logs. The summary of laboratory test results is also presented in a tabular form on Figures B-1 through B-7 in Appendix B. Grain size distribution curve is presented on Figure B-8 in Appendix B.

4.0 SUBSURFACE AND SITE CONDITIONS

4.1 Geology of the Coastal Plain

The geology of Harris County is characterized by two formations. The Beaumont formation is located in the southeastern portion of the county and the Lissie formation is located in the northwest. Both the Beaumont and the Lissie formations are part of the fluvial and marine coastal complex resulting from the glacial cycles within the Pleistocene/Holocene epoch. Seaward, the lithologies are primarily dominated by clays, often interspersed with coarser sediments, primarily silts and sands. Northern portions of Harris County are under the influence of the drainage systems established by rivers such as the Brazos and the San Jacinto. The lithologic pattern generally includes silt, sand and clay with minor amounts of calcareous nodules and iron oxide. Various mineral impregnations are associated with the lithologies. Primary among these are the ferruginous-iron-based and calcareous minerals, which include calcium carbonate. These minerals impart an acidic or alkaline characteristic to soils.

Based on the Texas, Geologic Atlas of Texas - Houston Sheet (Bureau of Economic Geology, University of Texas, 1982) the location of the project alignment is located on the Beaumont Formation. The clays and sands of this formation are overconsolidated as a result of desiccation or frequent raising and lowering of the sea level and subsequently the groundwater table. Consequently, clays of this formation have moderate to high shear strength and relatively low compressibility. Sands of the Beaumont Formation are typically very fine and often silty. Further, there is occasional evidence in the Houston area of the occurrence of cemented material (sandstone and siltstone) deposits within the Beaumont Formation.

There are two principal geologic hazards that are characteristic of these younger depositionals formation of the Pleistocene Epoch. The first is land surface subsidence which is the result of heavy pumpage of water from the underlying aquifers and to a lesser extent withdrawal of oil and gas. Since creation of the Harris-Galveston Coastal Subsidence District in the mid 1970s to regulate pumpage of groundwater, subsidence has been on the decline. Subsidence is not expected to impact this project. The second hazard is the presence of active growth faults and faults resulting from piercement of the formations by mobile salt masses. These faults are nontectonic and, in fact, Houston is located in a Seismic Zone of 0 according to the Uniform Building Code.

4.2 Natural Hazards

4.2.1 Subsidence - Land surface subsidence, related to groundwater pumpage and to a lessor extent, the withdrawal of oil and gas, has probably occurred in the Harris County area since the early settlers began to drill wells. During the period of 1906 to 2000, subsidence in the project area appears to have been between 7 and 8 feet.

In 1976, the State Legislature created the Harris-Galveston Subsidence District to regulate the pumpage of groundwater. Since creation of the district, the overall rate of subsidence in Harris County has been substantially reduced. Subsidence in the project area during the period of 1978 to 2000 appears to be between 0.5 and 1 feet. Subsidence in the project area during the period of 1995 to 2010 appears to be between 0 and 0.25 feet.

4.2.2 Geologic Faults in Vicinity of Site - A review of information in the Geotest library relating to known surface and subsurface geologic faults, in the general area of the project alignment, was undertaken. The available information consisted of U. S. Geological Survey maps, open file reports, and information contained in our files relating to geologic faults in the area.

Based on the review of the available information, the nearest known surface fault is of faults associated with Clinton Salt Dome which is approximately 1,000 feet north of the project alignment.

4.3 Site Stratigraphy and Geotechnical Characterization

Based on the subsurface soils encountered in the discrete boreholes drilled, two (2) boring log profiles were developed and are presented on Figures 3.1 and 3.2. To the left of each boring shown on the profile is an indication of the consistency or density of each stratum. More than one consistency or density for an individual stratum indicates that the consistency or density is different at different depths within the stratum. For cohesive soils, consistency is related to the undrained shear strength of the soil. For granular soils, the relative density is related to the standard penetration resistance of the soil. The symbols and abbreviations used on boring log profiles are given on Figure 4. To the right of each boring shown on the profile is the overall classification of the soil contained within each stratum. The classification is based on ASTM D2487.

The subsurface conditions for proposed 42-inch and 48-inch water lines, 60-inch water line extension, 84-inch Water Line Interconnect for Low Lift Pump Station Direct Connection and Pressure Regulating Station Project at EWPP are summarized below:

As revealed by boring logs GLLP-1 through GLLP-7, the subsurface soil below the existing grade consists of soft to hard brown, gray, yellowish brown and reddish brown Fat Clay, Lean Clay, Fat Clay w/sand, Lean Clay w/sand and Sandy Lean Clay to a depth of 25 feet, the explored depth in borings GLLP-3 through GLLP-7 and to a depth of 40 feet in boring GLLP-2. In boring GLLP-1, a stratum of medium dense gray Silty Sand was encountered between depths of 9.5 to 12 feet and very dense reddish brown Sandy Silt was encountered below 36 feet to the explored depth of 50 feet. In boring GLLP-2, the clays are underlain by dense to very dense reddish brown Silt to explored depth of 50 feet. A stratum of reddish brown Clayey Silt was encountered between the depths of 10 and 12 feet in boring GLLP-7. In borings GLLP-2, GLLP-4, GLLP-5 and GLLP-7, fill material consisting of medium stiff to very stiff brown, yellowish brown, gray and reddish brown Fat Clay, Fat Clay w/sand and Lean Clay w/sand, grass roots, calcareous and ferrous nodules was encountered to a depth of 6 and 10 feet below the existing grade.

The Sandy Lean Clay, Lean Clay w/sand and Lean Clay is of medium to high plasticity with a liquid limit ranging from 35 to 49 and plasticity indices ranging from 16 to 28. The Fat Clay and Fat Clay w/sand is of high to very high plasticity with liquid limits ranging from 50 to 78 and plasticity indices ranging from 29 to 50.

The percent fines (percent passing No. 200 sieve) of Sandy Lean Clay ranges from 54 to 68 percent. The percent fines of Lean Clay w/sand and Fat Clay w/sand ranges from 70 to 84 percent. The percent fines of Lean Clay and Fat Clay ranges from 88 to 99 percent. The percent fines of Sandy Silt is about 54 percent. The percent fines of Silt is about 92 percent.

4.4 Groundwater

The groundwater was encountered at depths ranging from 10 feet to 23 feet in all the borings GLLP-1 through GLLP-7 during drilling. The water level measured 20 minutes after water was first encountered is at depths ranging from 4.8 to 9.4 feet in these borings. The groundwater as observed on December 5, 2013 in Piezometer GLLP-5P is at depth of 4.2 feet. The ground water as observed on December 27, 2013 in piezometers GLLP-3P and GLLP-7P is at depths of 9.2 and 3.7 feet, respectively.

4.5 Environmental Issues

Nothing was observed or detected during our investigation to suggest any environmental concerns.

5.0 GEOTECHNICAL ENGINEERING RECOMMENDATIONS

The project consists of the design and construction of 84-inch, 60-inch, 48-inch and 42-inch waterlines, pressure regulating stations and control buildings to have a direct connection between existing 60-inch Raw Water Line at Plant 1 and 2, existing 84-inch Raw Water Line at Plant 3 and Low Lift Pump Stations (LLPS) at Plant 1 and 2 at East Water Treatment Plant.

5.1 Trench Excavation

5.1.1 Geotechnical Parameters. Based on the soil conditions revealed by the borings, geotechnical parameters were developed for the design of 42-inch water line, 48-inch water line, 60-inch water line extension and 84-inch Water Line Interconnect of the Low Lift Pump Station Direct Connection and Pressure Regulating Station at EWPP. The geotechnical design parameters are provided in Table 2. For design, the groundwater level should be assumed to exist at the ground surface, since these conditions may exist after a heavy rain or flooding.

5.1.2 Excavation Stability. It is understood that the proposed construction of 60-inch water line extension, 42-inch water line and 48-inch water line installation and 84-inch Water Line Interconnect is generally by open cut method except at the crossing of Hunting Bayou and Pipelines, where tunneling is proposed. The open excavation may be shored, laid back to a stable slope or supported by some other equivalent means used to provide safety for workers and adjacent structures. The excavating operations should be in accordance with OSHA Standards, OSHA 2207, Subpart P, latest revision and the City of Houston requirements.

- Excavation Shallower Than 5 Feet – Excavations that are less than 5 feet (critical height) deep should be appropriately protected when any indication of hazardous ground movement is anticipated.

- Excavations Deeper Than 5 Feet - Excavations that are deeper than 5 feet should be sloped, shored, sheeted, braced or laid back to a stable slope or supported by some other equivalent means or protection such that workers are not exposed to moving ground or cave-ins. The slopes and shoring should be in accordance with the excavation safety requirements per OSHA Standards. The following items provide design criteria for excavation stability.

(i) OSHA's Soil Type. Based on the soil conditions revealed by the borings and the design groundwater level, OSHA's soil type "C" should be used for the determination of allowable maximum slope and/or the design of a shoring system. For shoring deeper than 20 feet, an engineering evaluation is required.

(ii) Maximum Side-slopes. Based upon the results from the field and laboratory investigations of borings GLLP-1 through GLLP-7, it is our opinion that, temporary open-trench excavations with depths greater than 5-ft and less than about 20-ft, in general, may be made with slopes of 1.5(H):1(V) where sandy lean clay, lean clays and fat clays are encountered. When there are signs of distress or if water seepage is evident, the entire excavation must have side-slopes of 2(H):1(V). Trenches greater than 20 feet in depth must be designed by a professional engineer.

The Contractor designated "Competent Person" should review our recommendations and determine the appropriate safe slopes on the job site at the time of construction.

(iii) Excavation Support Earth Pressure. Based on the subsurface conditions indicated by this investigation and laboratory testing results, excavation support earth pressure diagrams were developed and are presented on Figures 5.1 through 5.3 (Reference 1). These pressure diagrams can be used for the design of temporary excavation bracing. For a trench box, a lateral earth pressure resulting from an equivalent fluid with a unit weight of 95 pcf is recommended. The above value of equivalent fluid pressure is based upon an assumption that the groundwater level is near the ground surface, since these conditions may exist after a heavy rain or flooding. Effect of surcharge loads at the ground surface should be added to the computed lateral earth pressures. A surcharge load, q, will typically result in a lateral load equal to 0.5 q. The example calculations of bracing pressures are presented in Appendix D.

(iv) Excavation Bottom Stability. In braced cuts, if tight sheeting is terminated at the base of the cut, the bottom of the excavation can become unstable under a certain conditions. This condition is governed by the shear strength of the soils and by the differential hydrostatic head between the groundwater level within the retained soils and the groundwater level at the interior of the trench excavation. For cuts in cohesive soils as encountered in the borings (Sandy Lean Clay, Lean Clay and Fat Clay), for excavation depths of 10 to 42 feet, stability of the bottom can be evaluated in accordance with the procedure outlined on Figure 6 (Reference 2). **For cut in cohesionless soils (Silty Sand, Clayey Silt, Sandy Silt and Silt) as encountered in borings GLLP-7 (between depths of 10 and 12 feet), GLLP-1 (between depths of 9.5 and 12 feet and between depths of 36 and 50 feet) and GLLP-2 (between depths of 40 and 50 feet), dewatering or other methods such as cutoff wall will be required to prevent bottom stability problems**. The details of excavation dewatering are addressed in Section 5.2.

5.1.3 Access Shaft for Tunneling. The access shafts proposed for the trenchless method should be constructed per City of Houston Standard Specifications, Section 02400 (tunnel shafts). The access shaft may be constructed by retained excavations or can be installed by sunken caisson. These methods are described below:

- Retained Excavation. Retained excavations generally require less ground surface area than open-cut excavation with laid back slopes. The retention system can consist of driven sheetpile, liner plates, solider pile/lagging, driven planking, or ring beams and timber lagging. The items pertaining to design criteria for retained excavation stability should be in accordance with guidelines as outlined in section 5.1.2.

- Sunken Caisson Installation. The caisson procedure eliminates the need for a temporary retention system. Caisson units can, however, experience problems with alignment and termination at the proper design depth. Stability considerations of the excavation bottom are similar to those for retained excavation techniques.

5.2 Excavation Dewatering

Excavations for the proposed 42-inch and 48-inch Water Lines, 60-inch Water Line Extension and 84-inch Water Line Interconnect at EWPP will encounter groundwater seepage to varying degrees depending upon the groundwater conditions at the time of construction and the location and depth of the trench or excavation.

Based on the soil conditions identified in the borings for the proposed 42-inch and 48-inch Water Lines, 60-inch Water Line Extension and 84-inch Water Line Interconnect, the excavations (based on excavation depths of 10 to 42 feet) will be in cohesive soils in borings GLLP-3, GLLP-4, GLLP-5 and GLLP-6A, cohesive with intermittent cohesionless or cohesive underlain by cohesionless soils in borings GLLP-1, GLLP-2 and GLLP-7, respectively.

In cohesive soil, groundwater may be managed by collection in trench bottom sumps for pumped disposal.

In cohesionless soil, dewatering such as well point system upto excavation depth of 15 feet and deep wells with submersible pumps for excavation greater than 15 feet deep will be required to lower the groundwater level to at least 5 feet below the level of excavation. The well point system or deep wells should be pumping well ahead of the time excavation starts so that a steady state condition (at least 5 feet below the proposed excavation bottom) is achieved.

In the area near Hunting Bayou where tunnel access shafts are proposed, dewatering may be carried out by using educator well system as sandy silt and silt were encountered at the bottom of the anticipated shaft excavations (as revealed by borings GLLP-1 and GLLP-2). In the area near boring

GLLP-7 (in the vicinity of Foreby area), eductor well system may be used for the dewatering as clayey silt was encountered near the bottom of the trench excavation. However, in the vicinity of Hunting Bayou and Foreby areas, if dewatering cannot be achieved effectively to lower the ground water level, other method such as an interlock sheet pile cut off wall with sufficient penetration below the bottom of excavation can be installed to cut off the seepage of water into the excavation area. The minor seeping water can then be controlled by a cut off trench leading to a sump and pump.

It is recommended that the actual groundwater conditions be verified at the time of construction and that the groundwater control be performed in general accordance with the City of Houston Standard Specifications, Section 01578. It should be noted that actual methods and means of ground water control and construction safety are the contractor's responsibility.

5.3 Vehicular Traffic and Railroad Loads

It should be noted that the proposed water lines are not crossing any railroad, hence specific information regarding the railroad loads does not apply to this project.

The proposed construction of water lines is generally installed by open cut method except at the crossing of Hunting Bayou crossing and pipelines, where tunneling is proposed. The proposed 42-inch and 48-inch Water Lines, 60-inch Water Line Extension and 84-inch Water Line Interconnect will be steel pipe. The vertical load on underground conduit will be based on type of installation and type of pipe i.e. rigid or flexible.

5.3.1 Vertical Earth Pressure on Ditch Conduit. The vertical load on an underground conduit depends principally on the weight of the prism of soil directly above it. In the case of a ditch conduit, the backfilling material has a tendency to consolidate and settle downward. This action plus the settlement of the conduit into its soil foundation causes the prism of soil within the ditch and above the pipe to move downward relative to the undisturbed soil at the sides. This relative movement along the sides of the ditch mobilizes certain shearing stresses or friction forces which act upward in direction and which, in association with horizontal forces, create an arch action that partially supports the soil backfill. The difference between the weight of the backfill and these upward shearing stresses is the load that must be supported by the conduit at the bottom of the ditch.

- Flexible Pipe Conduit. Under soil load, a flexible pipe tends to deflect, thereby developing passive soil support at the sides of the pipe. At the same time, the ring deflection relieves the pipe of the major portion of the vertical soil load which is picked up by the surrounding soil in an arching action over the pipe. However, a convenient design for a flexible pipe (e.g., steel pipe) would be the prism load which is the weight of a vertical prism of soil over the pipe. The prism load is given by the following equation:

	P_c	=	γH
or	W_c	=	$\gamma H\, B_c$ (Reference 3)
in which	P_c	=	pressure due to weight of soil, psf
	W_c	=	vertical load per unit length of conduit, lb/linear ft
	γ	=	wet unit weight of backfill material, pcf (recommended 120 pcf)
	H	=	height of fill above top of pipe (conduit), feet
	B_c	=	outside diameter of pipe, feet

- Rigid Pipe Conduit. For the case of a rigid conduit with relatively compressible side fills, the load on the conduit will be:

	W_d	=	$C_d\, \gamma\, B_d^2$ (Reference 4)
where	W_d	=	fill load in lbs/linear ft. of conduit
	C_d	=	trench load coefficient
	γ	=	wet unit weight of backfill material, pcf (recommended 120 pcf)
	B_d	=	width of trench at or slight below the level of the top of the conduit, in feet

The trench load coefficient C_d is a function of the trench depth to width ratio and the frictional characteristics of the backfill material and sides of the trench. C_d can be determined using the following equation:

$$C_d = \frac{1 - e^{-2K\mu'\left(\frac{H}{B_d}\right)}}{2K\mu'} \qquad \text{(Reference 4)}$$

where K = $\tan(45° - \phi'/2)$ = Rankine's ratio of active lateral unit pressure to vertical unit pressure, with ϕ' = friction angle between backfill and soil

μ' = $\tan \phi'$ = coefficient of friction between fill material and sides of trench

H = height of fill above top of pipe, in feet

B_d = width of trench at top of pipe in feet

For design, $K\mu' = 0.150$ may be used for saturated top soil.

<u>5.3.2 Load on Conduit Due to Traffic Loads</u>. In addition to the vertical earth pressure or overburden, underground conduits are also subject to live loads, such as wheel loads applied at the surface of the backfill and transmitted through the soil to the underground structure. The live load on the conduit due to traffic loads can be calculated using the following equation.

$$W_L = \frac{W_T}{L_e} \qquad \text{(Reference 4)}$$

where W_L = live load on pipe, in pounds per linear feet

W_T = total live load in pounds

L_e = effective supporting length of pipe, in feet

L_e is determined by the following equation:

L_e = $L + 1.75\,(3B_c/4)$ (Reference 4)

where L = length of A_{LL}, parallel to longitudinal axis of pipe, in feet

B_c = outside diameter of pipe, in feet and W_T is the total live load acting on pipe is given by:

W_T = $w_L L S_L$ (Reference 4)

where w_L = average pressure intensity in pounds per square foot given by

$$w_L = \frac{WH(I_f)}{A_{LL}} \quad \text{(Reference 4)}$$

WH = total applied surface wheel loads, in pounds

A_{LL} = distributed live load area in square feet

I_f = Impact factor (use 1.0 as height of cover is 3 feet or greater)

S_L = outside horizontal span of pipe or width of A_{LL}, transverse to longitudinal axis of pipe, whichever is less, in feet

Depending on height of cover and wheel load, A_{LL}, distributed live load area can be computed from the following table (Reference 4):

Height of Cover *(ft)*	Wheel Load *(lb)*	A_{LL}, Distributed Load Area *(ft x ft)*	
H<1.33	16,000	(0.83 + 1.75H)	(1.67 + 1.75H)
1.33 < H < 4.10	32,000	(0.83 + 1.75H)	(5.67 + 1.75H)
4.10 < H	48,000	(4.83 + 1.75H)	(5.67 + 1.75H)

Loads on the pipe due to vehicular traffic crossing should also be considered. A graph providing calculated vertical stress on pipe due to traffic loads is given on Figure 7. The load, whichever gives higher value due to traffic, should be considered for design.

5.3.3 Pipe Bedding and Backfill. It is recommended that the City of Houston Standard Specification 02511 “Water Lines” and Standards Drawing No.02317-04 should be followed for bedding and backfill.

5.3.4 Shaft Backfill. The excavated shafts should be backfilled per City of Houston Standard Specifications, Section 02400, “Tunnel Shafts,” Subsection 3.04.

5.3.5 Influence of Open Cut Excavation on Adjacent Structures. Based on the information available to us, the open cut excavation for the proposed 48-inch Water Line, 60-inch Water Line Extension and 84-inch Water Line Interconnect are generally through the easement and there are no immediate building structures along the proposed excavations. However, underground utilities may be adjacent to the excavations and should be properly protected during excavations and monitored during and after the excavation and dewatering.

5.4 Pressures on Primary and Permanent Liners

The proposed 42-inch and 48-inch water lines, 60-inch water line extension crossing pipelines and 84-inch Water Line Interconnect crossing Hunting Bayou will be installed by bore and jack method of tunneling.

However, at Hunting Bayou Crossing, the trenchless method of construction will require the use of the proper construction technique and good quality of workmanship. As shown on the boring log profile presented on Figure 3.1, the Hunting Bayou bottom (approximate El. -12.00 ft.) will be in cohesive soils with 100-year flood level at El. 12.50 ft. **Thus, the proposed 84" steel water line placed at approximate El. -34.0 ft. to be constructed by trenchless method will require the use of the proper tunneling equipment that can fully breast the excavation face and the contractor has sufficient knowledge and significant experience to work under the bayou with soil conditions such as water bearing sandy silt and silt at and below the invert depth at Hunting Bayou.**

5.4.1 Geotechnical Parameters for Trenchless Installation. Based on the soil conditions revealed by the borings GLLP-1, GLLP-2, GLLP-6A and GLLP-5 and laboratory test data, geotechnical design parameters were developed for cohesive soils and cohesionless soils. The geotechnical design parameters are provided in Tables 3.1 through 3.3. The cohesive soils include Fat Clay, Lean Clay and Lean Clay w/sand, and the cohesionless soils include sandy silt and silt. For design conditions, the groundwater levels should be assumed to exist at the ground surface, since this condition may exist after a heavy rain or flooding.

5.4.2 Earth Pressure on Tunnel. The earth pressures on the tunnel liner should be determined from Figure 8 (Reference 5). Equations to calculate the tunnel liner loads are also shown in Figure 8. For tunnel crossing under the major streets, the stress due to traffic loads should be constructed. The relationship between the depths of pipe and the vertical stress on the pipe due to traffic live loads is provided on Figure 7.

5.4.3 Carrier Pipe Design Parameters. Carrier pipe must be sufficiently strong to withstand anticipated long-term ground loads and must not be subject to deterioration by substance either in the ground or in the tunnel. The carrier pipe design should include consideration of not only the loads applied to the pipe but also factors other than soil loading. These factors could include minimum structural code requirements, loading from pipe jacking operations and other construction loads. The drained geotechnical design parameters given in Table 3 should be used in analyzing the soil structure intersection of the carrier pipe.

5.5 Piping System Thrust Restraint

Unbalanced thrust forces will occur at any point in the pipe where the direction or cross sectional area of the flow changes. The force diagram shown on Figure 9 (Reference 4) illustrates the thrust force generated by flow at a bend in the pipe. The equations for computing this thrust force are also given on this figure. The thrust force will often require more resistance or support than is available just from the pipe bearing against the backfill. In order to prevent intolerable movement and overstressing of the pipe, suitable buttressing should be provided.

Based on the drawings provided to us, it was noted that several horizontal bends are proposed which may require restraint in addition to that supplied by the pipe bearing on the backfill. In general, thrust blocks, and restrained joints are common methods of supplying additional reaction. However, we understand that restrained joints are planned for the pipe restraint and are discussed below:

Restrained Joints. Restrained joints, allowing thrust and shear forces to be transmitted across the pipe joints, are employed to allow a number of pipe sections to act integrally in bearing. The equations necessary to determine the restrained pipe length on each side of the bend is given below:

$$L = \frac{PA \quad Sin\,(\theta / 2)}{f\ (2\,W_e + W_p + W_w)} \qquad \text{(Reference 4)}$$

where L = restrained pipe length on each side of the bend, in feet

P = internal pressure, in pounds per square inch

A = cross sectional area of first unrestrained pipe joint, in square inches

θ = deflection angle of bend, in degrees

f = co-efficient of friction between pipe and soil (recommended 0.3)

W_e = over burden load, in pounds per linear foot = $\gamma_b B_C H$

W_p = weight of pipe, in pounds per linear foot

W_w = weight of water in pipe, in pounds per linear foot

γ_b = wet unit weight of backfill material in pounds per cubic foot (recommended 120 pcf)

B_c = pipe outside diameter, in feet

H = earth cover, in feet

5.6 Influence of Tunneling on Adjacent Structures

Surface and near-surface structures near the tunnel alignment consist primarily of public utilities, bayou and private pipelines.

Ground movement, in terms of loss of ground or ground lost, is commonly associated with soft ground tunneling. If such ground movement is excessive, it may cause damage to the structures, roads and services located above the tunnel. While ground movement cannot be eliminated, it can be controlled within certain limits by the use of proper construction techniques and good quality workmanship. These include, but are not limited to, prevention of excessive ground loss during tunneling with the use of grouting and filling the annular space between the pipe or casing and the surrounding soil and prevention of undue loss of fines through dewatering.

The selection and execution of tunneling methods that are best suited to anticipated ground conditions along the proposed tunnel are, in fact, the contractor's primary contribution to successful completion of the proposed tunnel. On review of the boring logs, the ground conditions for tunneling (excavation face) along Hunting Bayou crossing (borings GLLP-1 and GLLP-2) will be through soft to hard fat clay and lean clay underlain by dense to very dense sandy silt and silt near the crown of the pipe. The ground at this segment may be expected to behave as firm to raveling ground with possible cohesive running to flowing ground near the invert (without dewatering) or raveling to cohesive running ground near the invert (with dewatering). The ground conditions for tunneling (excavation face) along pipeline crossing (borings GLLP-5 and GLLP-6a) will be primarily through stiff to very stiff Sandy Lean Clay, Lean Clay w/sand and Fat Clay and the ground may be expected to behave as firm (stable) ground with possible swelling. However due to spacing of borings, soil conditions other than those encountered in borings could exist. **In view of sandy silt and silts encountered within the tunnel diameter near borings GLLP-1 and GLLP-2, dewatering is recommended in these areas.**

The proposed tunnel is parallel with or crosses beneath a number of water, gas, power and telephone lines. The largest potential problems from utilities may result from:

- Leakage water pipes
- Gas pipe breakage leading to a potential problem
- Breakage of storm and sanitary sewers

In general, it is the contractor's responsibility to investigate these and other possible third party interactions along the proposed tunnel alignment and to accommodate all of these interactions with the use of good construction methods.

5.7 Lateral Earth Pressure Diagrams

Based on information provided to us, the structures for this project will consist of vaults, BFV w/operator manholes, Air Release Valve w/access manhole and access manholes.

The pressure diagrams provided on Figures 5.1 through 5.3 can be used for the design of braced excavation. The lateral earth pressure diagrams presented on Figures 10.1 through 10.3 (Reference 1) are applicable for the design of the permanent walls of the structures.

5.8 Allowable Bearing Pressures and Hydrostatic Uplift Resistance

5.8.1 Allowable Bearing Pressures. Based on the soil conditions revealed by the borings GLLP-1, GLLP-2, GLLP-4, GLLP-5 and GLLP-7, the structure bases will be in stiff to very stiff fat clay, lean clay and lean clay w/sand.

The bases of structures placed at approximate depths ranging from 10 to about 42 feet at the various locations may be proportioned for an allowable (net) bearing pressure as given below.

Structures	**Nearest Boring No.**	**Approximate Foundation Depths, feet**	**Allowable (Net) Bearing Pressure, psf**
BFV w/operator manhole at Sta. 2+22; ARV w/access manhole at Sta. 3+18	GLLP-7	10	3000
CWA Vault at Sta. 2+50 and Sta. 2+90	GLLP-7	15	6000
BFV w/operator manhole at Sta. 7+63	GLLP-6A	19	2000
BFV w/operator manhole at Sta. 10+45 and Sta. 10+80	GLLP-5	19	2500
City Vault at Sta. 10+60	GLLP-5	15 to 18	2500

Structures	**Nearest Boring No.**	**Approximate Foundation Depths, feet**	**Allowable (Net) Bearing Pressure, psf**
BFV w/operator manhole at Sta. 12+30 and Sta. 12+83	GLLP-4	19	4200
City Vault at Sta. 12+55	GLLP-4	15 to 18	4200
Access Manhole at Sta. 14+50	GLLP-4	16	5000
Access Manhole at Sta. 24+00	GLLP-3	11	4000
Access Manhole at Sta. 31+95	GLLP-2	35	1000
Access Manhole at Sta. 34+75	GLLP-1 and GLLP-2	42	6000

The allowable bearing pressures include a factor of safety of 2.0. The recommendations of the allowable bearing pressures given above assume that the final bearing surface consists of undisturbed natural soils, underlying transmissive zones are properly pressure-relieved, and stable undisturbed bearing surfaces are attained.

The other design parameters for vaults are given below:

Structure Location	**Nearest Boring Number**	**Approximate Foundation Depth (ft)**	**Equivalent Fluid Density, pcf/ft. depth**		**Sliding Friction**		**Vertical Modulus of Subgrade Reaction, pci**
			At Rest	**Active**	**Coefficient**	**Adhesion, psf**	
CWA Vault at Sta. 2+50, 2+90	GLLP-7	15	126	94	0.3	1200	50
City Vault at Sta. 10+60	GLLP-5	15 to 18	130	96	0.34	500	30
City Vault at Sta. 12+55	GLLP-4	15 to 18	128	95	0.35	1000	35

5.8.2 Hydrostatic Uplift Resistance. Structures extending below the groundwater level should be designed to resist uplift pressure resulting from excess piezometric head. Design uplift pressures should be computed based on the assumption that the water table is at ground surface. To resist the hydrostatic uplift at the bottom of the structures, one of the following sources of resistance can be utilized in each of the designs.

a. Dead weight of structure,
b. Weight of soil above base extensions plus weight of structure, or
c. Soil-wall friction plus dead weight of structure.

The uplift force and resistance to uplift should be computed as detailed on Figure 11 (Reference 5). In determining the configuration and dimensions of the structure using one of the approaches presented on Figure 11, the following factors of safety are recommended.

a. dead weight of concrete structure, S_{f1} = 1.10,
b. weight of soil(backfill) above base extension, S_{f2} = 1.5, and
c. soil-wall friction, S_{f3} = 3.0.

Friction resistance should be discounted for the upper 5 feet, since this zone is affected by seasonal moisture changes.

5.8.3 Groundwater Control During Construction. Excavations will encounter groundwater seepage. The ground water control should be in accordance with the guidelines as addressed in Sections 5.2 "Excavation Dewatering."

5.9 Pipe Support at Low Lift Pump Station No. 2

It was noted that drilled shafts were proposed to support pipe above ground at Low Lift Pump Station No. 2.

Based on subsurface conditions encountered in borings GLLP-4 and GLLP-5, soil parameters were developed for the computation of axial capacity of drilled shafts. Summary of Design Soil

Parameters are presented on Table 4. Using the parameters presented on Table 4 and the design guidelines included in "Drilled Shafts: Construction Procedures and Design Methods" published by the Federal Highway Administration, the allowable axial capacity for individual straight-sided 36-inch diameter drilled shaft was developed for soil conditions based on borings GLLP-4 and GLLP-5. The curves of allowable axial capacity for individual straight-sided 36-inch diameter drilled shaft is presented on Figure 12. The values of the allowable axial capacity include factors of safety of 2.0 applied to the ultimate unit friction and 3.0 applied to the ultimate unit end bearing. Furthermore, it should be noted that in computing axial capacity, the contribution to axial capacity of the top five (5) feet of soil has been neglected for seasonal moisture changes.

5.10 Protection of Below Grade Structures

The design of proper means for the protection of below grade structures will depend upon the potential of the aggressivity or corrosivity of soil and groundwater properties. The aggressive test or corrosivity test of soil and the design of the protection of below grade structures is beyond the scope of services for this study.

5.11 City Control Building

It is our understanding that city buildings will be constructed at grade near Sta. 3+50 and Sta. 10+90 for LLPS Direct Connection and PRS at EWPP. The loading of the building is about 1,500 lb/sq. ft. The geotechnical recommendations for the buildings are summarized below.

5.11.1 Foundation Type, Depth and Allowable Bearing Pressure. Based on the information provided, we understand that the new control buildings will be at the existing grade with minimal cut and fill. As revealed by borings GLLP-5 and GLLP-7, the surficial soils consists of 6-feet of fat clay fill soils (medium stiff to very stiff clay w/grass roots and gravel) underlain by high plasticity fat clay. These high plasticity fat clay fill and fat clays have high potential for shrink/swell movements. **Hence, the slab-on-grade foundation is not feasible unless the foundation subgrade is properly treated to reduce the swelling and shrinkage potential of clay soils. The subgrade treatment is described**

below:

It is recommended to excavate and remove to a depth of at least 4 feet of soils in the building slab area and extend at least 5 feet beyond the slab area and replaced with structural fill as addressed in "Site Preparation and Structural Fill Requirement" section of this report. The slab-on-grade foundation supported on 48 inches of compacted structural fill material can be designed for an allowable (net) bearing pressure of 3,750 psf for total loads or 2,500 psf for sustained loads whichever results in the larger foundation area. These bearing pressures contain safety factors of 2 and 3, respectively.

5.11.2 Foundation Settlement. Depending upon the footing size and magnitude of the sustained footing pressure, some total and differential settlements should be anticipated due to consolidation of the foundation soils. Although detailed settlement analysis was not within the scope of this study, it is believed that the footings designed in accordance with the above recommendations should experience small acceptable settlements. Small differential settlement may also result from variation in subsurface conditions across the site, loading conditions and construction procedures.

5.11.3 Grade Beams. To minimize the excessive changes in the moisture content of the soils beneath the slab, the exterior grade beams should extend at least 24 inches below the finished grade. The grade beams should have tensile reinforcement both at the top and at the bottom of the beam.

5.11.4 Landscaping. It is recommended that no large trees exist or be planted within 15 feet of the building and preferably within the mature drip line. Any flowerbeds or open lawn areas, if provided near the building areas, should have a good sprinkler system to minimize the moisture variations in the subsurface soils. It is imperative that the sprinkler systems installed in the proximity of structures be free from leaks, which could provide a continuous source of moisture and promote differential swelling of the near surface soils.

5.11.5 Surface Drainage. The following drainage precautions should be observed during construction and maintained at all times after the building has been completed:

1. All backfill soils around the building should be moistened and compacted to at least 95 percent of Standard Proctor Density (ASTM D 698).

2. The ground surface surrounding the exterior of the building should be sloped to drain away from the building in all directions.

3. Roof downspouts and drains should discharge well beyond the limits of the foundation backfill and into pipes or paved areas.

5.11.6 Site Preparation and Structural Fill Requirements. The existing fill soil should be removed in the building area. The site should be cleared of all debris, grubbed and stripped of all organic material, soft soils and foreign material from the building and paved areas. Stripped areas should be appropriately graded and shaped to prevent ponding of water on the site.

Should any structural fill required to raise the grade or backfill grub holes should consist of silty or sandy clay with a liquid limit less than 40 and a plasticity index between 10 and 20. The structural fill should be compacted at moisture content within three percent above optimum to reduce swelling potential of the compacted fill. The fill material should be placed in loose lifts not exceeding eight inches and should be compacted to a minimum of 98 percent of the maximum dry density as determined by ASTM D 698 in building area and 95 percent of the maximum dry density as determined by ASTM D 698 in parking area. The structural fill should extend at least five feet outside the building and paving area. The onsite surficial high plasticity clay soils are not suitable for structural fill, unless stabilized with sufficient lime.

5.11.7 Building Pad. During construction, it is essential that the finished surface be protected from excessive drying. Any material required to raise the grade should meet the criteria described in the section "Site Preparation and Structural Fill Requirements." The structural fill, if needed, should extend at least 5 feet beyond the slab area.

5.11.8 Floor Slab Construction. Due to high potential for swelling and shrinkage of the surficial soils, the floor slabs should be supported on 36 inches of inactive fill material. This inactive material should be select structural fill meeting the criteria described in the previous section, "Site Preparation and Structural Fill Requirements."

6.0 LIMITATIONS

The description of subsurface conditions and the design information contained in this report are based on the test borings made at the time of drilling at specific locations. However, some variation in soil conditions may occur between test borings. Should any subsurface conditions other than those described in our borings be encountered, Geotest should be immediately notified so that further investigation and supplemental recommendations can be provided.

The depth of the groundwater level may vary with changes in environmental conditions such as frequency and magnitude of rainfall. The stratification lines on the log of borings represent the approximate boundaries between soil types, however, the transition between soil types may be more gradual than depicted.

7.0 AUTHORIZATIONS AND CREDITS

LAN was selected by City of Houston to provide engineering design and construction program management services in support Surface Water Transmission Program (SWTP) Projects. LAN then selected Geotest Engineering, Inc. to provide geotechnical engineering services related to the design and construction of 48-inch, 60-inch and 84-inch water lines for Low Lift Pump Station Direct Connection and Pressure Regulating Station project.

This report has been prepared for the exclusive use of LAN or City of Houston for the design and construction of the SWTP LLPS Direct Connection and PRS project.

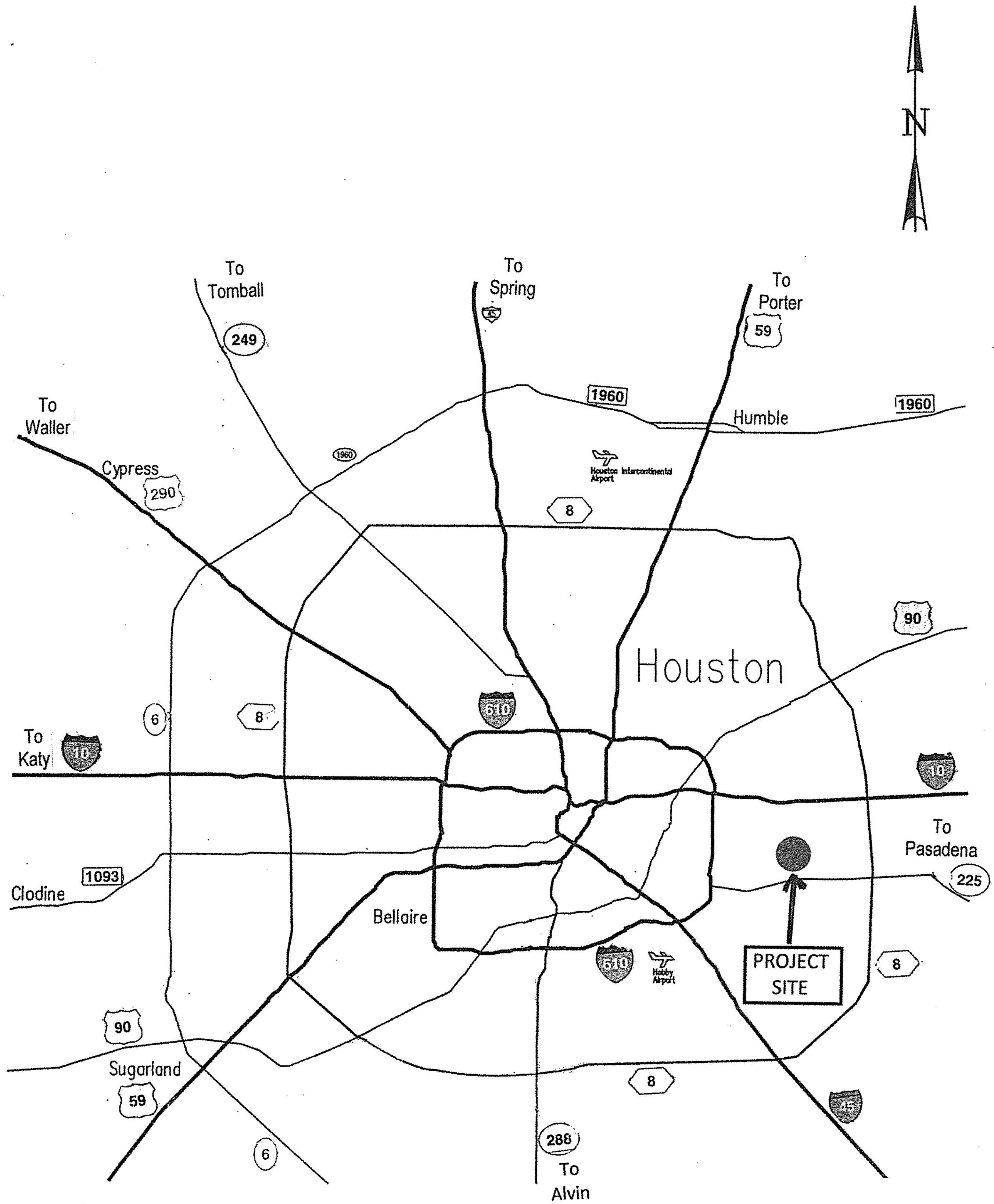
This report shall not be reproduced without the written permission of Geotest Engineering, Inc., LAN or the City of Houston.

8.0 REFERENCES

1. Das, Braja M. (1999), *Principles of Foundation Engineering*, 4th Edition, Brooks/Cole Publishing Company, Pacific Grove, CA.
2. Department of the Navy (1982), *Foundations and Earth Structures Design Manual 7.2*, Naval Facilities Engineering Command, Alexandria, VA.
3. American Water Works Association, *Manual of Water Supply Practices, Steel Pipe-A Guide for Design and Installation*, AWWA Manual M11, Thrid Edition, American Water Works Association, Denver, CO.
4. American Water Works Association, *Manual of Water Supply Practices, Concrete Pressure Pipe*, AWWA Manual M9, Second Edition, American Water Works Association, Denver, CO.
5. Geotest Engineering, Inc., Houston, Texas.

ILLUSTRATIONS

Job No. 1140193801

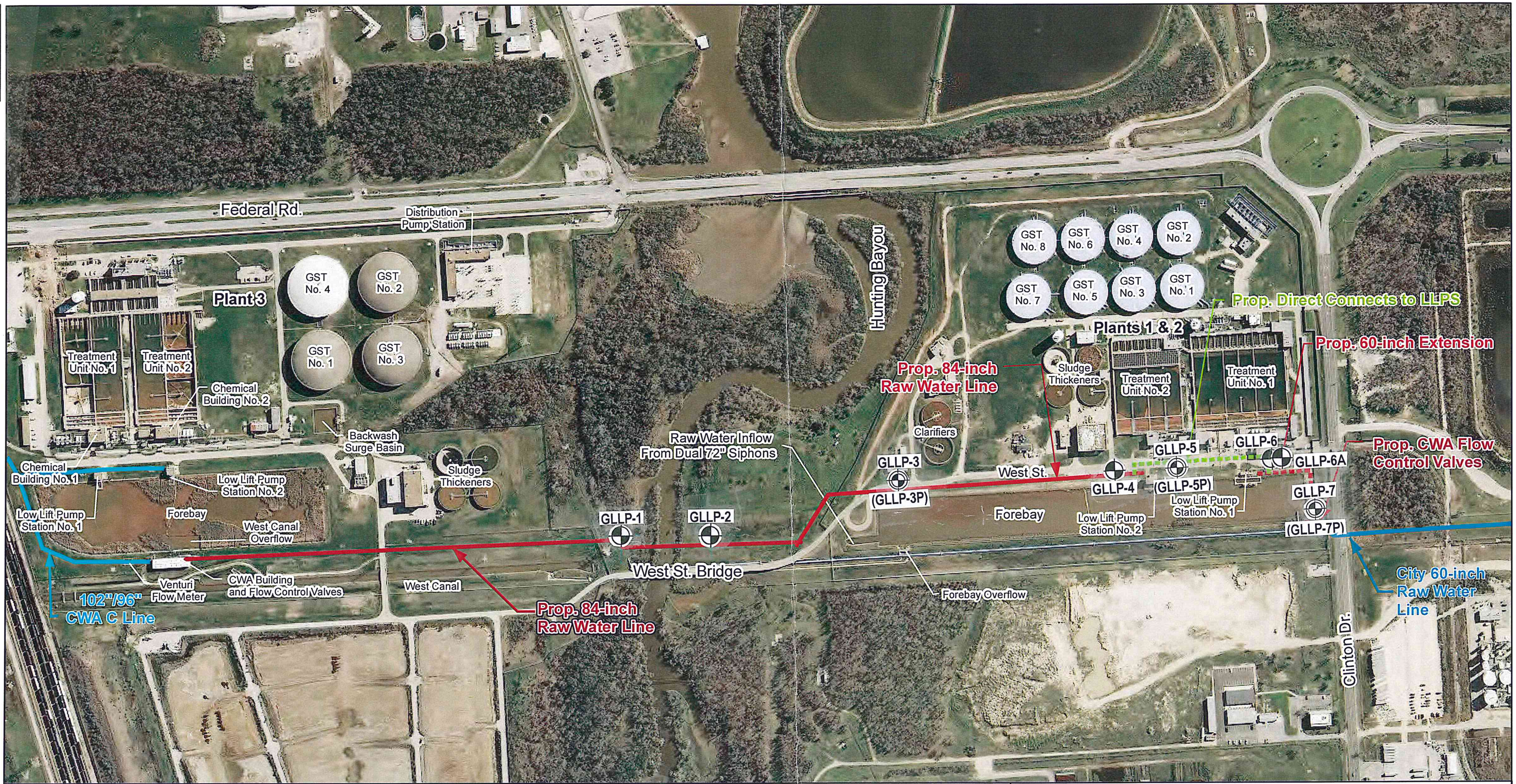


VICINITY MAP
(NOT TO SCALE)

Geotest Engineering, Inc.

FIGURE 1

Job No.: 1140193801



- Prop 84-inch Raw Water Line
- Prop 60-inch Extension
- Diret Connects to LLPS
- CWA "C" Raw Water Line
- City 60-inch Raw Water Line

Legend:

Boring

Boring with Piezometer

N E S W

0 200 400 800 Feet

Note: Boring GLLP-1 is not drilled at the time of report preparation

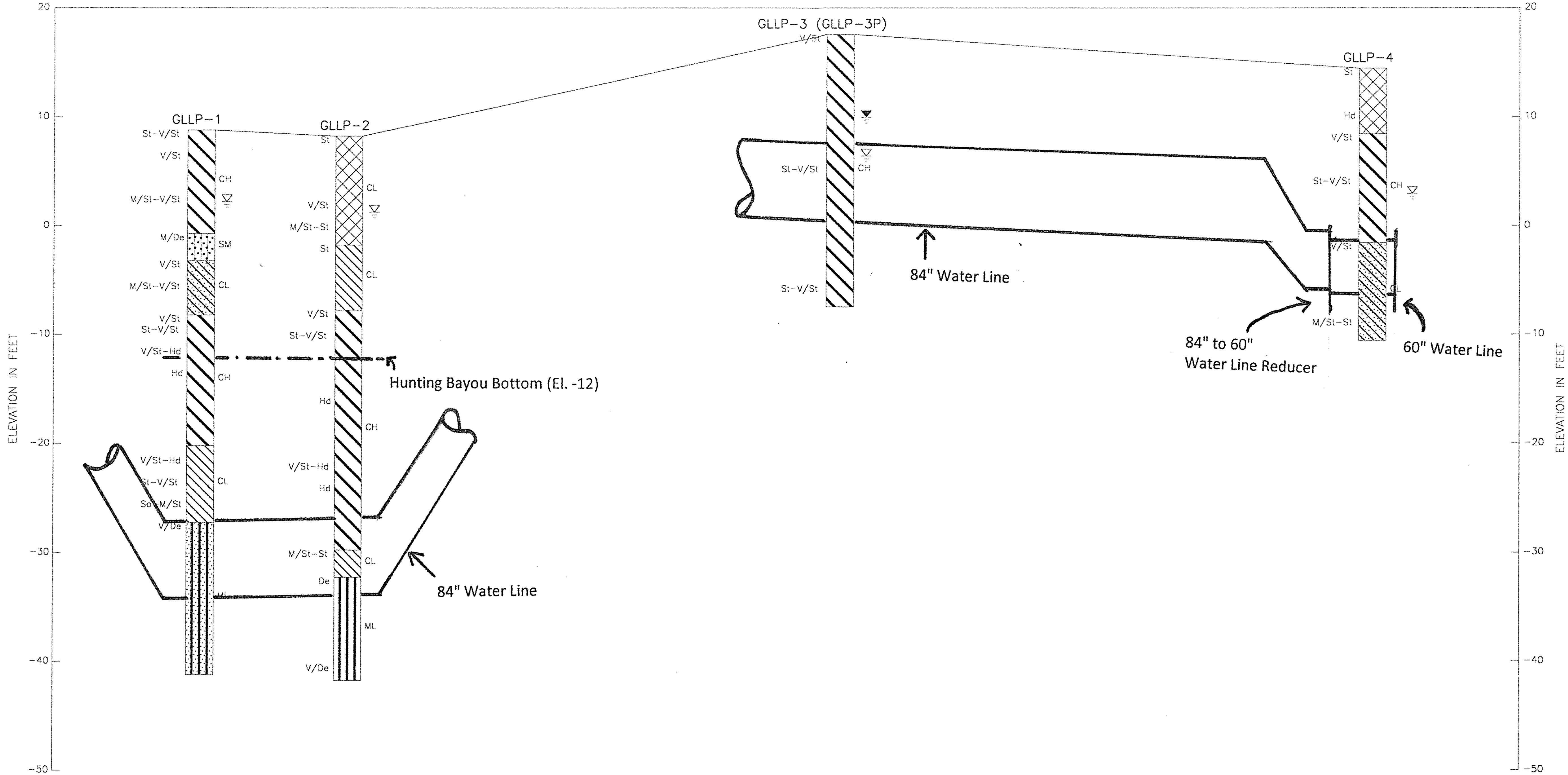
EAST WATER PURIFICATION PLANT (EWPP)

WBS No. S-000902-0132-3
84-inch Interconnection @ EWPP
PLAN OF BORINGS
WBS No. S-000902-0133-3
LLPS Direct Connection and PRS @ EWPP

PROJECT LOCATION MAP

Path: L:\130-10557-020\9-0-Non-Projectwise_Data\9-01-GIS\MXD\Recommended alignment - Borehole Location.mxd Date Saved: 10/23/2013 10:01:00 AM

FIGURE 2



GENERAL NOTES:

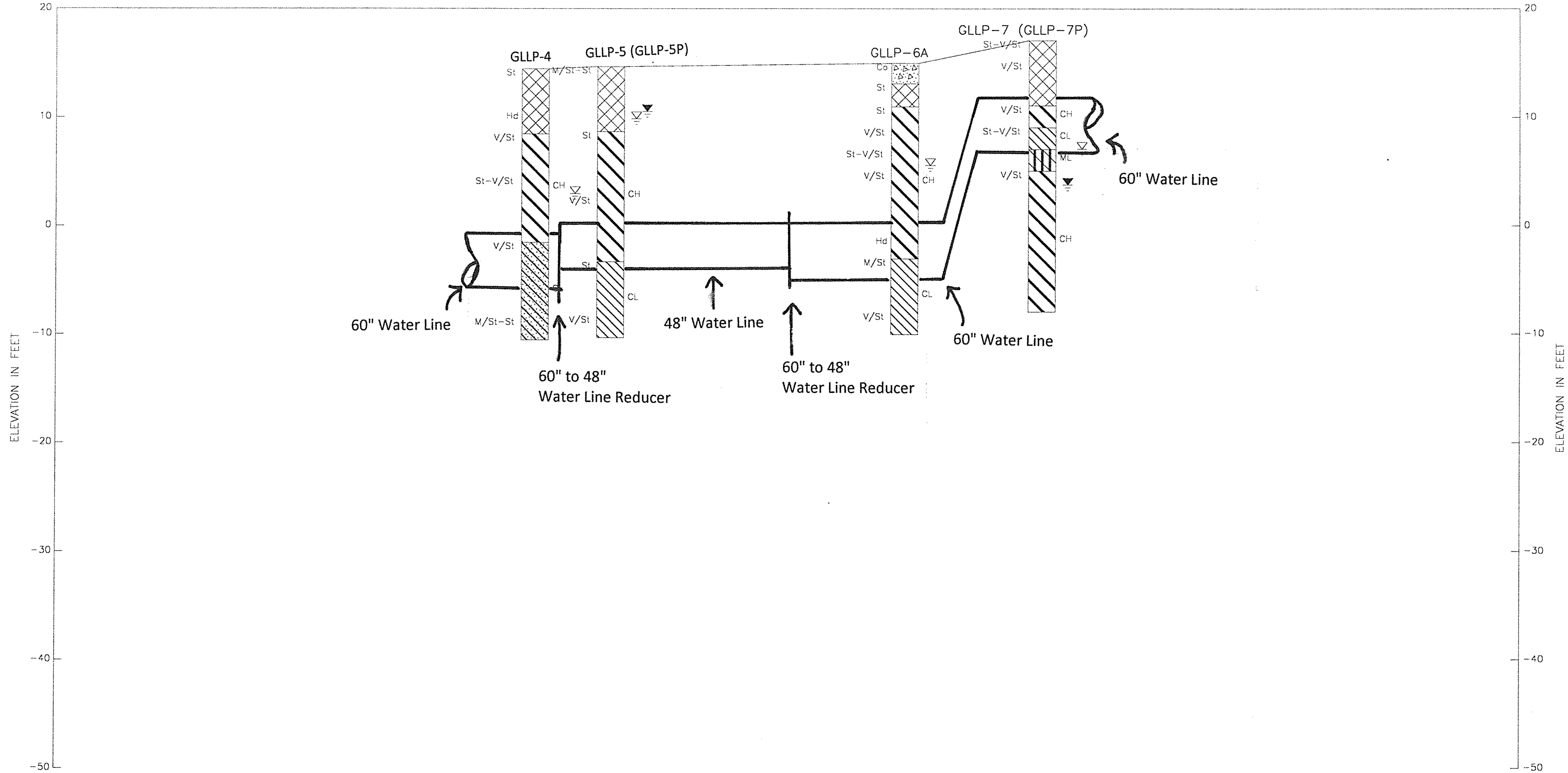
1. See Figure 2 for approximate location of borings and profile section.
2. Data concerning subsurface conditions have been obtained at boring locations only. Actual conditions between borings may differ from the profile shown here.
3. See logs of boring for detailed description of soils encountered in each borehole.
4. See Figure 4 for symbols and abbreviations used on this profile.
5. Ground surface elevation at each boring location was based on survey data provided to us by LAN, Inc.

BORING LOG PROFILE

LLPS Direct Connection and PRS at EWPP

0 100 200 300 400

HORIZONTAL SCALE IN FEET



GENERAL NOTES:

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2. Data concerning subsurface conditions have been obtained at boring locations only. Actual conditions between borings may differ from the profile shown here.
3. See logs of boring for detailed description of soils encountered in each borehole.
4. See Figure 4 for symbols and abbreviations used on this profile.
5. Ground surface elevation at each boring location was based on survey data provided to us by LAN, Inc.

BORING LOG PROFILE

LLPS Direct Connection and PRS at EWPP

0 100 200 300 400

HORIZONTAL SCALE IN FEET

Job No. 1140193801

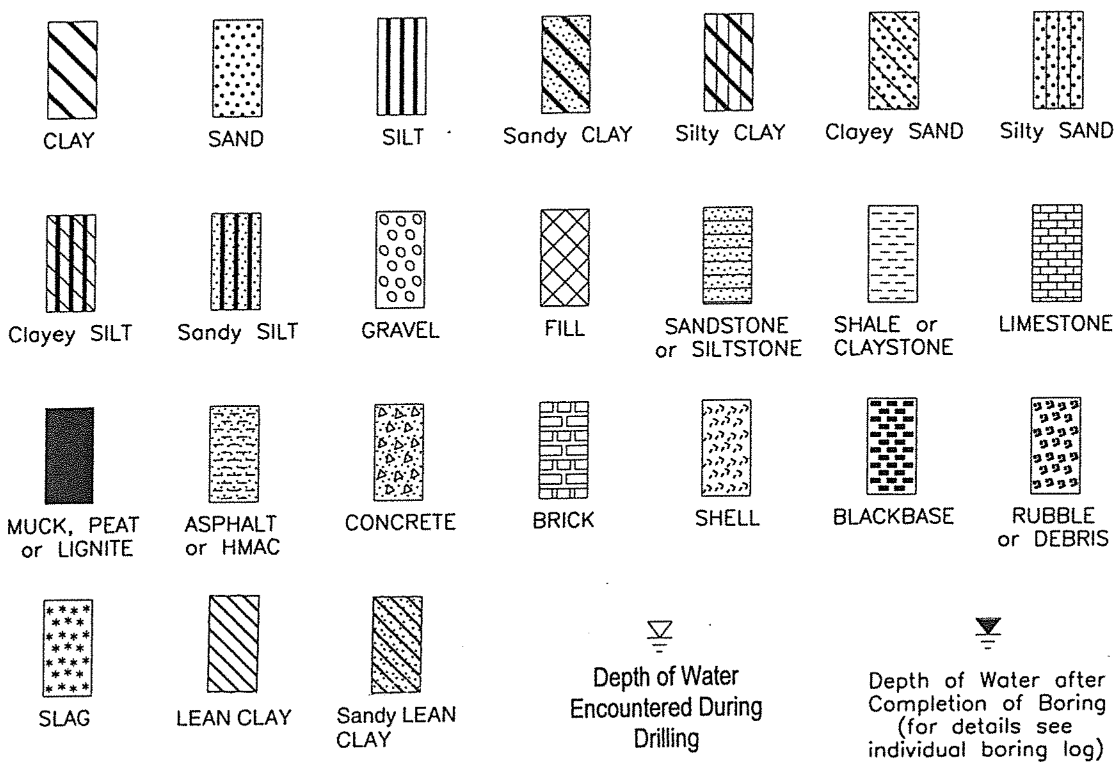
Geotest Engineering, Inc.

FIGURE 3.2

Job No. 1140193801

SYMBOLS AND ABBREVIATIONS USED ON BORING LOG PROFILE

LEGEND



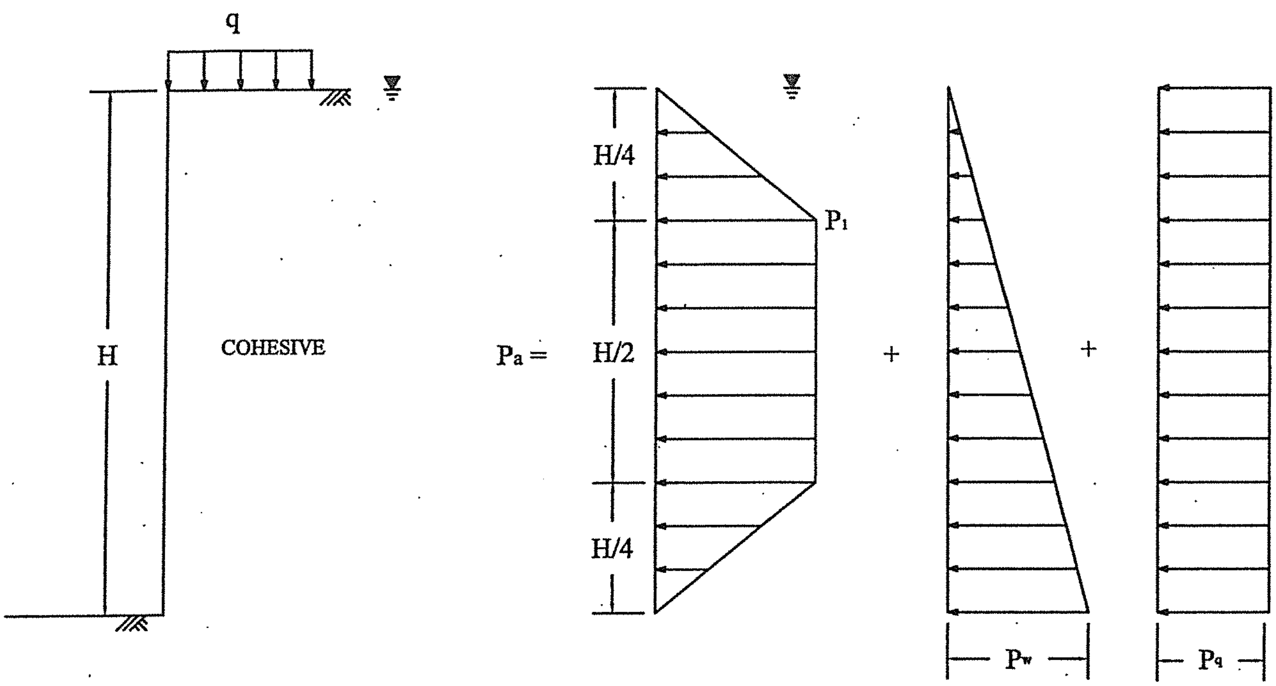
ABBREVIATIONS USED FOR CONSISTENCY/DENSITY

COHESIVE SOILS

- V/So : Very Soft
- So : Soft
- Fm : Firm
- M/St : Medium Stiff
- St : Stiff
- V/St : Very Stiff
- Hd : Hard
- V/Hd : Very Hard

COHESIONLESS SOILS

- V/Lo : Very Loose
- Lo : Loose
- S/Co : Slightly Compact
- Co : Compact
- M/De : Medium Dense
- De : Dense
- V/De : Very Dense



TYPICAL SOIL PARAMETERS

See Table 2 for typical values of soil parameters

BRACED WALL

For $\gamma H/c \leq 4$

$P_1 = 0.3\ \gamma_c'\ H$
$P_w = \gamma_w\ H = 62.4\ H$
$P_q = 0.5\ q$

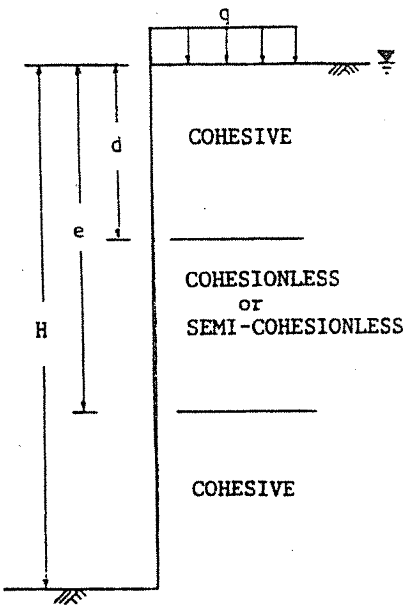
Where:

- γ_c' = Submerged unit weight of cohesive soil, pcf;
- γ_w = Unit weight of water, pcf;
- q = Surcharge load at surface, psf;
- P_a = Lateral pressure, psf;
- P_1 = Active earth pressure, psf;
- P_q = Horizontal pressure due to surcharge, psf;
- P_w = Hydrostatic pressure due to groundwater, psf;
- H = Depth of braced excavation, feet
- c = Shear strength of cohesion soil, psf;

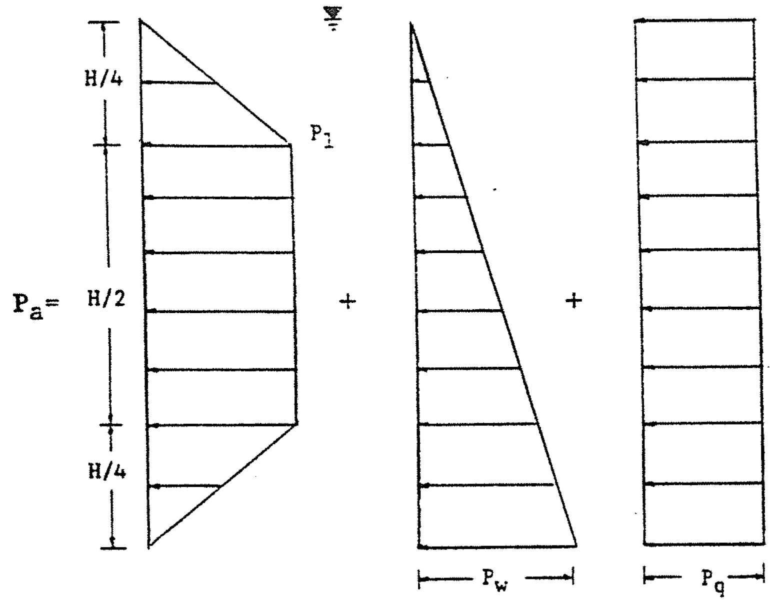
EXCAVATION SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL

Job No. 1140193801



TYPICAL SOIL PARAMETERS



BRACED WALL

See Table 2 for typical values of soil parameters

$P_1 = 0.3\ \gamma'_{avg}\ H$

$P_w = \gamma_w\ H = 62.4\ H$

$P_q = 0.5_q$

$$\gamma'_{avg} = \frac{\gamma_c'\ d + \gamma_s'\ (e-d) + \gamma_c'\ (H-e)}{H}$$

$\gamma_w = 62.4$ pcf

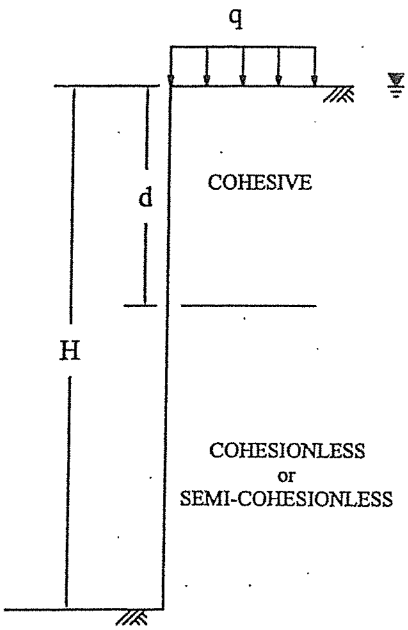
Where:

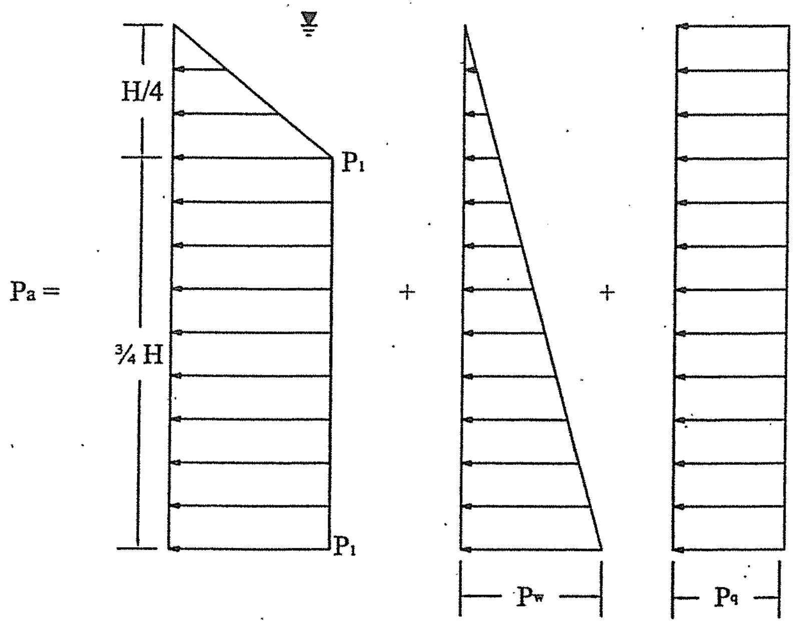
- γ_c' = Submerged unit weight of cohesive soil, pcf ;
- γ_s' = Submerged unit weight of cohesionless or semi-cohesionless soil, pcf ;
- γ_w = Unit weight of water, pcf;
- γ'_{avg} = Average submerged unit weight of soil, pcf ;
- q = Surcharge load at surface, psf;
- P_a = Lateral pressure, psf;
- P_1 = Active earth pressure, psf;
- P_q = Horizontal pressure due to surcharge, psf;
- P_w = Hydrostatic pressure due to groundwater, psf;
- H = Depth of braced excavation, feet

EXCAVATION SUPPORT EARTH PRESSURE

SUMBERGED COHESIVE SOIL
INTERBEDDED WITH COHESIONLESS OR
SEMI-COHESIONLESS SOIL

Job No. 1140193801





TYPICAL SOIL PARAMETERS

BRACED WALL

See Table 2 for typical values of soil parameters

$$\gamma'_{avg} = \frac{\gamma_c' \, d + \gamma_s' \, (H-d)}{H}$$

$P_1 = 0.3 \, \gamma'_{avg} \, H$
$P_w = 62.4 \, H$
$P_q = 0.5 \, q$

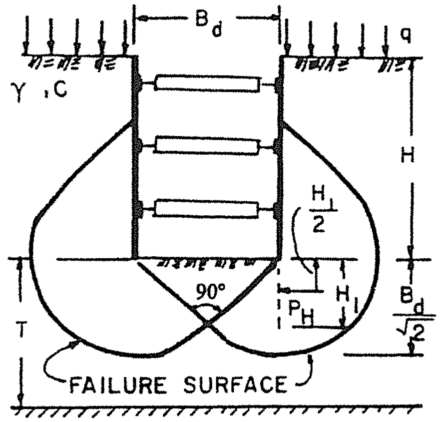
Where:

γ_c' = Submerged unit weight of cohesive soil, pcf;
γ_s' = Submerged unit weight of cohesionless soil, pcf;
γ'_{avg} = Average submerged unit weight of soils, pcf;
q = Surcharge load at surface, psf;
P_a = Lateral pressure, psf;
P_1 = Active earth pressure, psf;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Depth of braced excavation, feet

EXCAVATION SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL OVER
COHESIONLESS OR SEMI-COHESIONLESS SOIL

CUT IN COHESIVE SOIL,
DEPTH OF COHESIVE SOIL UNLIMITED ($T > 0.7\ B_d$)
L = LENGTH OF CUT



If sheeting terminates at base of cut:

$$\text{Safety factor, } F_S = \frac{N_C C}{\gamma H + q}$$

N_C = Bearing capacity factor, which depends on dimensions of the excavation : B_d, L and H (use N_C from graph below)

C = Undrained shear strength of clay in failure zone beneath and surrounding base of cut

γ = Wet unit weight of soil (see Table 2)

q = Surface surcharge (assume q = 500 psf)

If safety factor is less than 1.5, sheeting or soldier piles must be carried below the base of cut to insure stability - (see note)

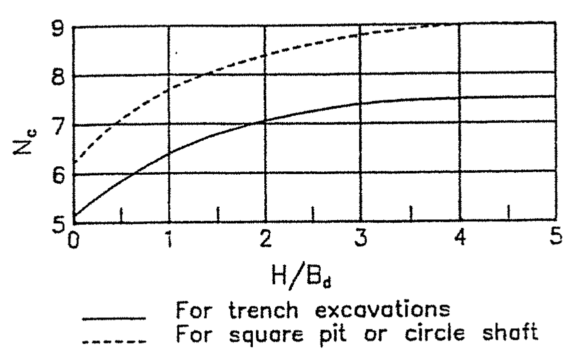
$$H_1 = \text{Buried length} = \frac{B_d}{2} \geq 5 \text{ feet}$$

Note : If soldier piles are used, the center to center spacing should not exceed 3 times the width or diameter of soldier pile .

Force on buried length, P_H:

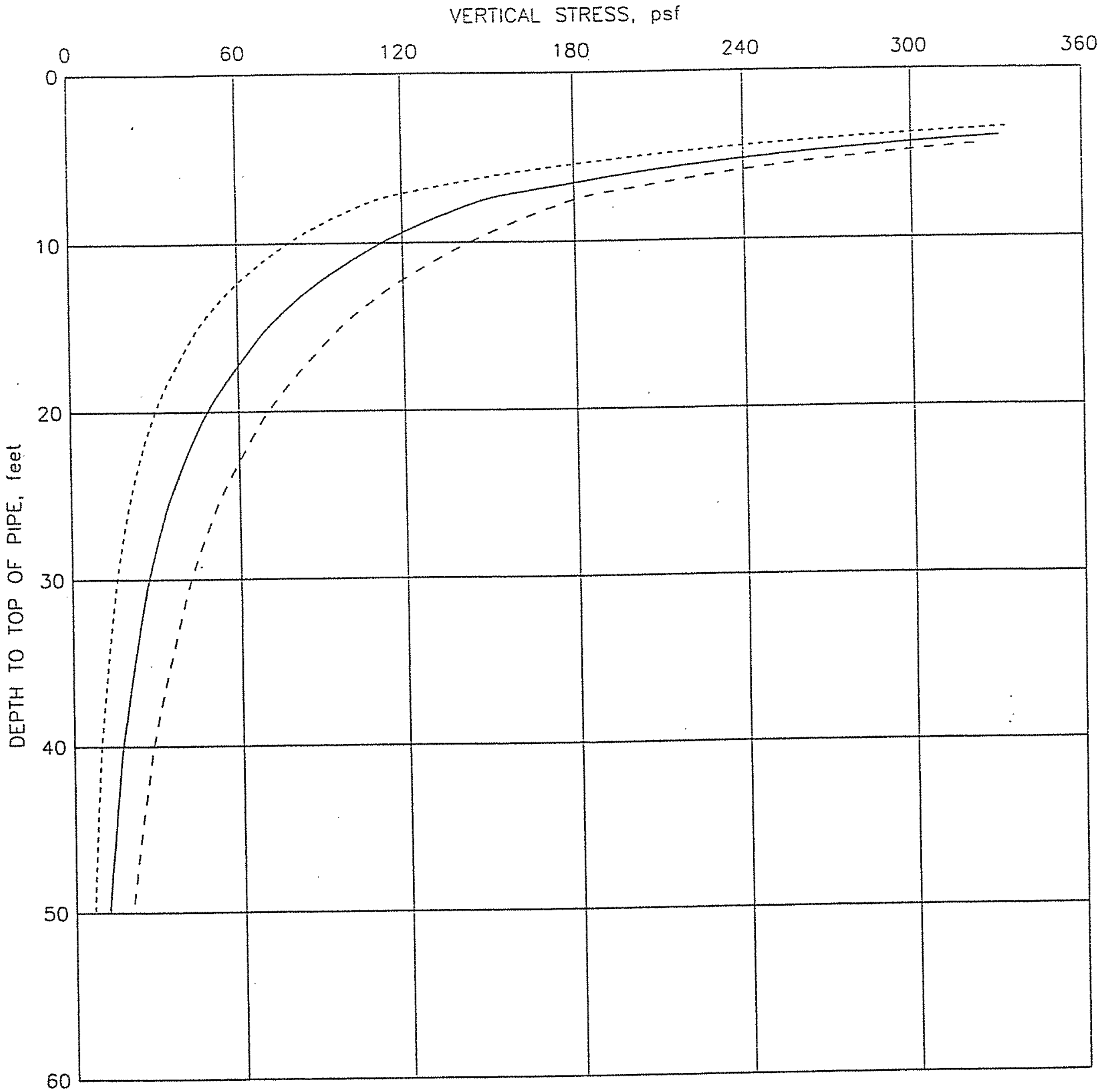
If $H_1 > \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 0.7\ (\gamma HB_d - 1.4CH - \pi CB_d)$ in lbs/ linear foot

If $H_1 < \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 1.5H_1\ (\gamma H - \frac{1.4CH}{B_d} - \pi C)$ in lbs/ linear foot



STABILITY OF BOTTOM FOR BRACED CUT

Job No. 1140193801

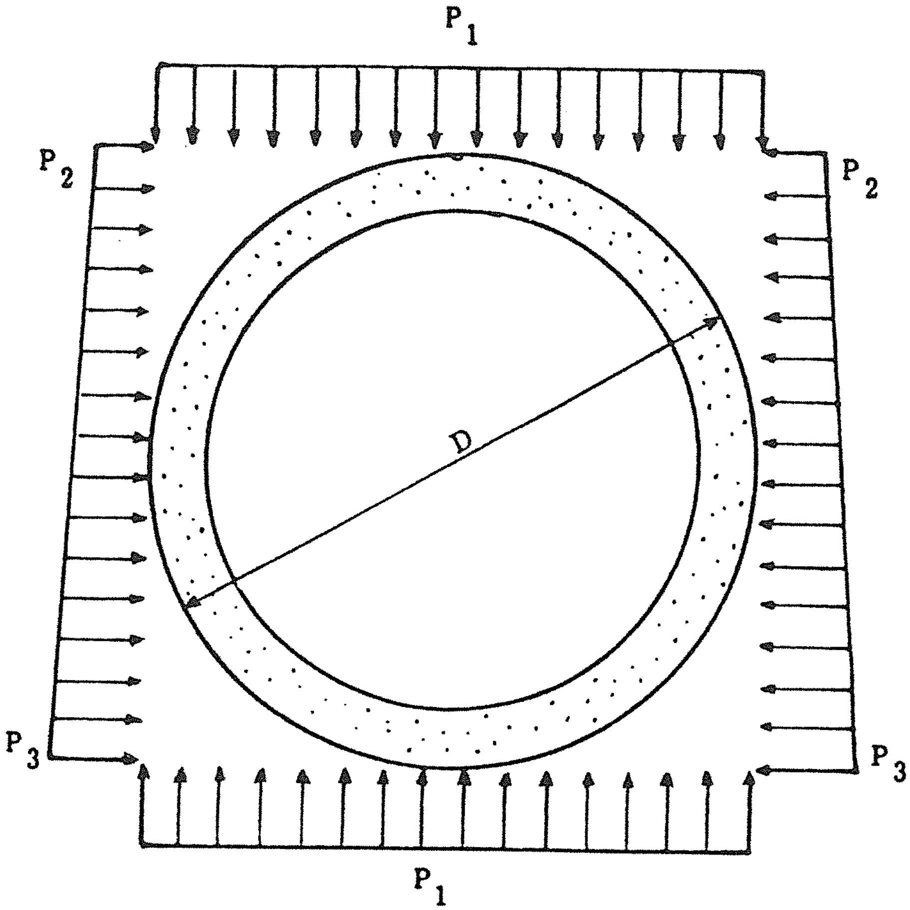


Legend:

------ One passing truck
—— Two passing trucks
_ _ _ Four passing trucks

Notes: 1. The vertical stress was estimated using AASHTO H20 or HS20 truck axle loadings on paved surfaces.
2. Impact factor was included in the vertical stress.

VERTICAL STRESS ON PIPES
DUE TO TRAFFIC LOADS



$$P_1 = [(H + \frac{D}{2}) \times (\gamma - \gamma_w) + D_w \times \gamma_w] + q_s \text{ , for } D_w < H + \frac{D}{2}$$

$$P_1 = [(H + \frac{D}{2}) \times \gamma] + q_s \text{ , for } D_w \geq H + \frac{D}{2}$$

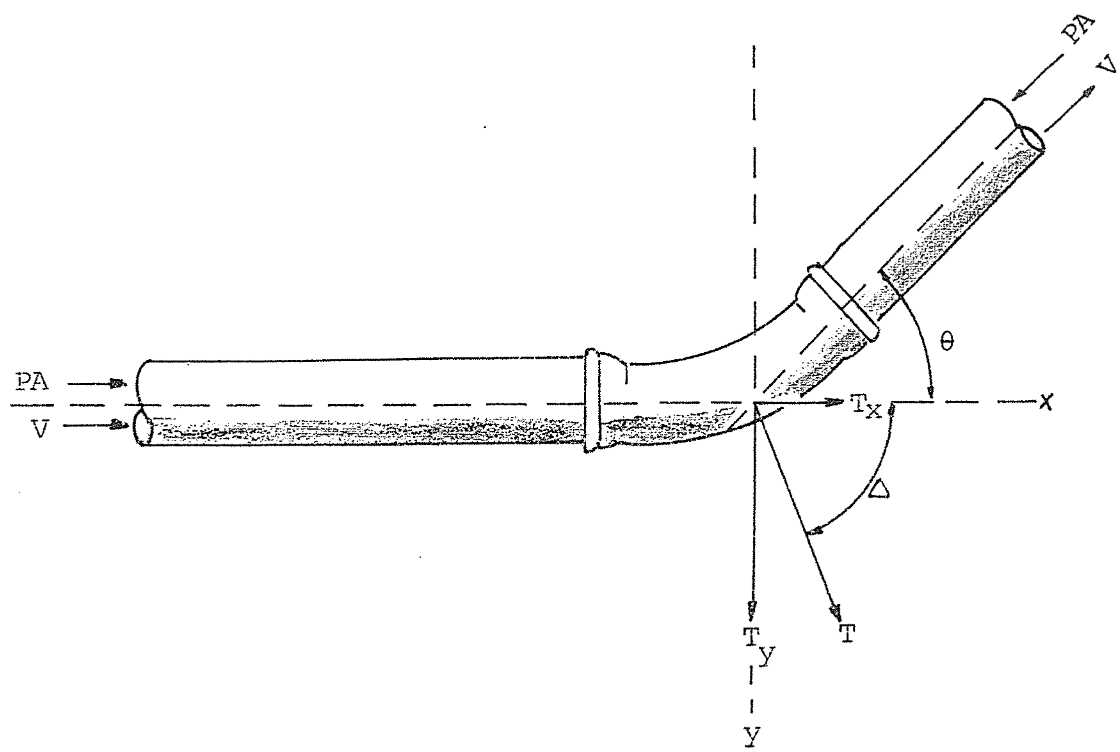
$$P_2 = (H \times \gamma) + q_s$$

$$P_3 = [(H + D) \times \gamma] + q_s$$

Where: P_1, P_2, P_3 = Tunnel liner load, psf.
D = Tunnel outside diameter, ft.
H = Depth to top of tunnel; ft.
D_w = Depth to ground water level; ft.
γ = Wet unit weight of soil, pcf (see Table 3)
γ_w = Unit weight of water, 62.4 pcf
q_s = Surcharge load, psf.
K_o = Coefficient of Lateral Earth Pressure at rest

TUNNEL LINER LOADS

Job No. 1140193801



$$T_x = PA\ (1 - \cos\theta)$$

$$T_y = PA \sin\theta$$

$$T = 2\ PA \sin\frac{\theta}{2}$$

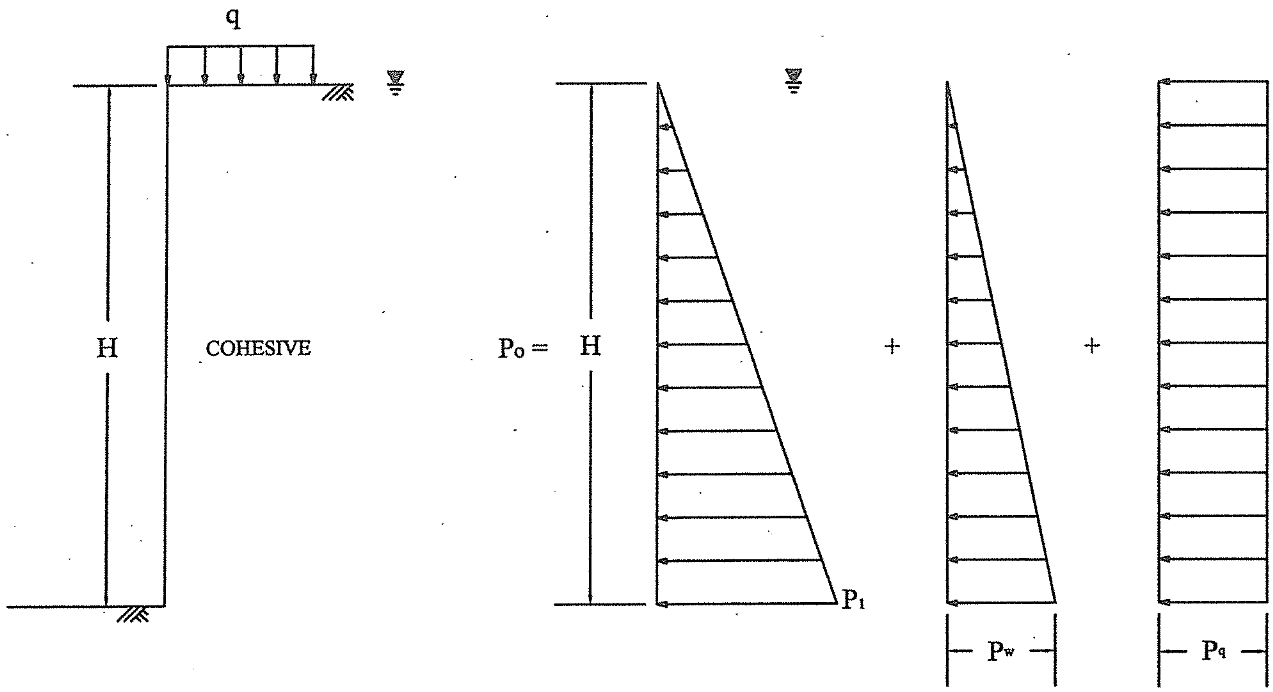
$$\Delta = \left(90 - \frac{\theta}{2}\right)$$

Where:

- T is the resultant force on the bend
- T_x is the component of thrust force in x-direction
- T_y is the component of thrust force in y-direction
- P is the maximum sustained pressure
- A is the pipe cross-sectional area
- θ is the bend deflection angle
- Δ is the angle between T and X-axis
- V is the fluid velocity

THRUST FORCES ACTING ON A BEND

Job No. 1140193801



TYPICAL SOIL PARAMETERS

See Table 2 for typical values of soil parameters

$K_{oc} = 1.0$

PERMANENT WALL

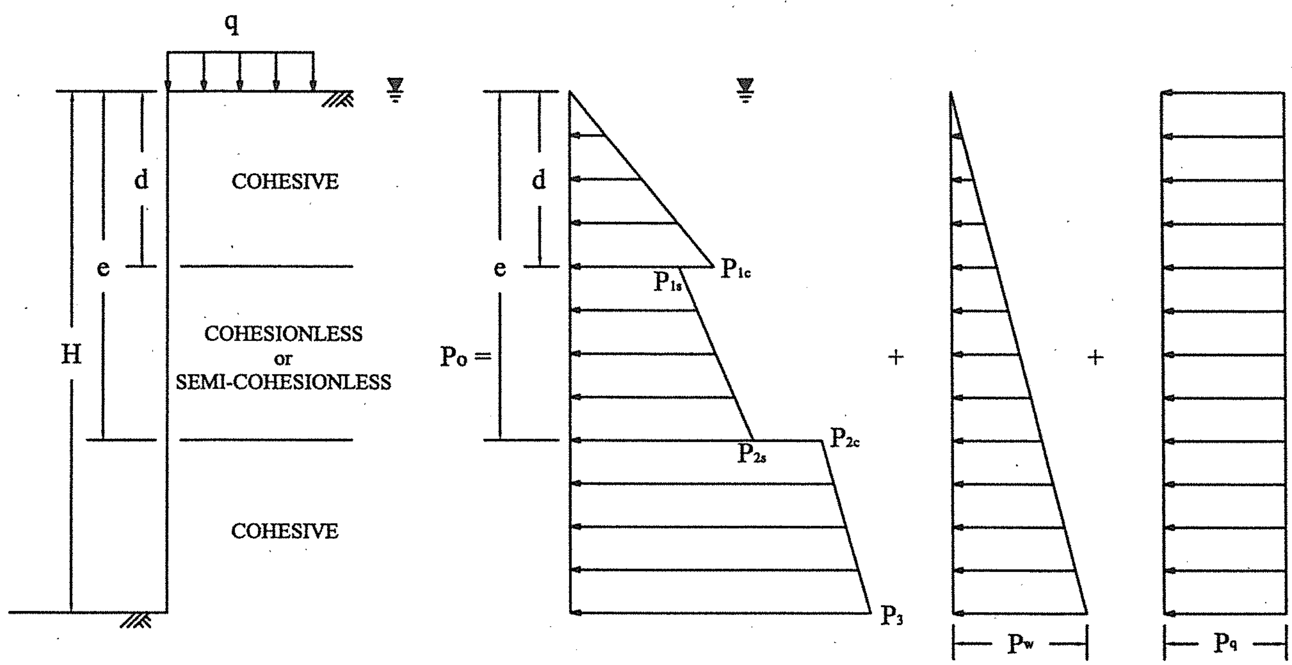
$P_1 = K_{oc}\, \gamma_c'\, H$
$P_w = \gamma_w\, H = 62.4\, H$
$P_q = 0.5\, q$

Where:

γ_c' = Submerged unit weight of cohesive soil, pcf;
K_{oc} = Coefficient of at-rest earth pressure in cohesive soil;
γ_w = Unit weight of water, pcf;
q = Surcharge load at surface, psf;
P_o = Lateral pressure, psf;
P_1 = At-rest earth pressure, psf;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Depth of excavation, feet

LATERAL EARTH PRESSURE DIAGRAM FOR PERMANENT WALL

SUBMERGED COHESIVE SOIL



TYPICAL SOIL PARAMETERS

See Table 2 for typical values of soil parameters

$K_{oc} = 1.0$
$K_{os} = 1 - \sin \phi_s$
$\gamma_w = 62.4$ pcf

PERMANENT WALL

$P_{1c} = \gamma_c'\, d\, K_{oc}$
$P_{1s} = \gamma_c'\, d\, K_{os}$
$P_{2s} = P_{1s} + \gamma_s'\, (e-d)\, K_{os}$
$P_{2c} = [\gamma_c'\, d + \gamma_s'\, (e-d)]\, K_{oc}$
$P_3 = [\gamma_c'\, d + \gamma_s'\, (e-d) + \gamma_c'\, (H-e)]\, K_{oc}$
$P_w = \gamma_w\, H = 62.4\, H$
$P_q = 0.5\, q$

Where:

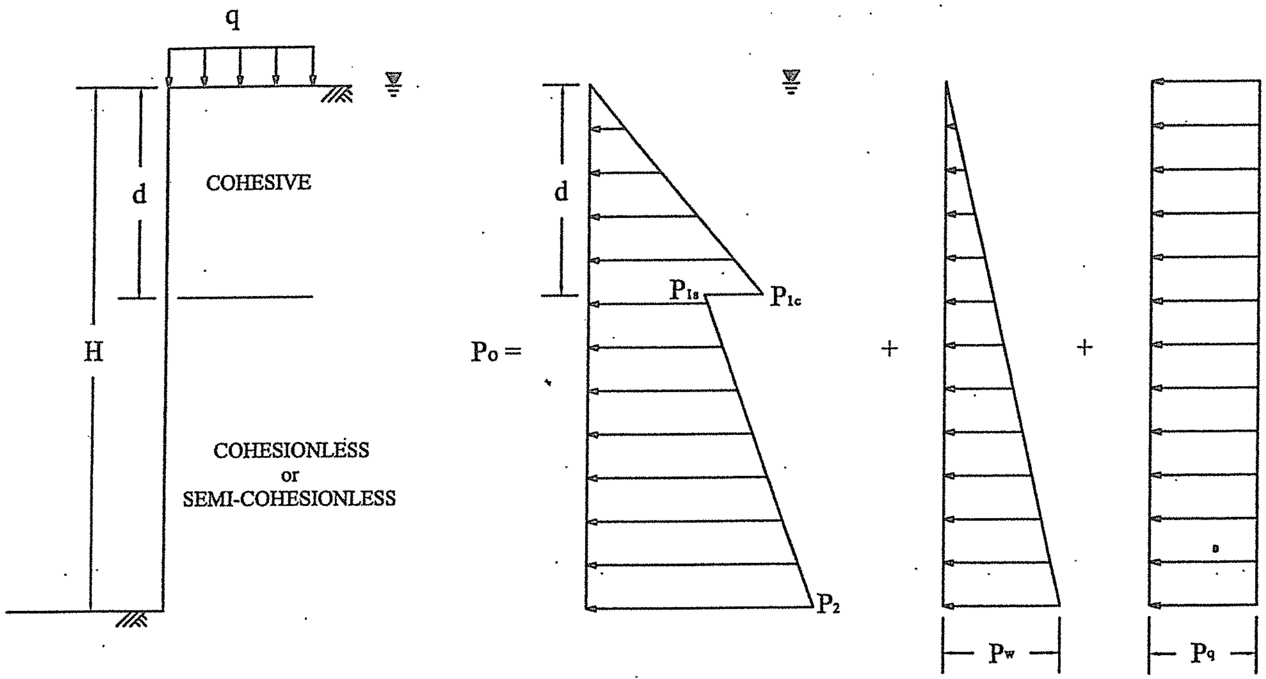
γ_c' = Submerged unit weight of cohesive soil, pcf;
γ_s' = Submerged unit weight of cohesionless or semi-cohesionless soil, pcf;
ϕ_s = Internal friction angle of cohesionless or semi-cohesionless soil, degree;
K_{oc} = Coefficient of earth pressure at rest in cohesive soils;
K_{os} = Coefficient of earth pressure at rest in cohesionless or semi-cohesionless soil;
γ_w = Unit weight of water, pcf;
q = Surcharge load at surface, psf;
P_o = Lateral pressure, psf;
P_i, P_{ic}, P_{is} = Earth pressure at rest, psf; i = 1, 2, 3;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Height of wall, feet

LATERAL EARTH PRESSURE DIAGRAM FOR PERMANENT WALL

SUBMERGED COHESIVE SOIL INTERBEDDED WITH COHESIONLESS OR SEMI-COHESIONLESS SOIL

Geotest Engineering, Inc.

FIGURE 10.2



TYPICAL SOIL PARAMETERS

See Table 2 for typical values of soil parameters

$K_{oc} = 1.0$
$K_{os} = 1\text{-}\sin\phi_s$

PERMANANT WALL

$P_{1c} = \gamma_c' \, d \, K_{oc}$
$P_{1s} = \gamma_c' \, d \, K_{os}$
$P_2 = [\gamma_c' \, d + \gamma_s' \, (H\text{-}d)] \, K_{os}$
$P_w = \gamma_w \, H = 62.4 \, H$
$P_q = 0.5 \, q$

Where:

γ_c' = Submerged unit weight of cohesive soil, pcf;
γ'_s = Submerged unit weight of cohesionless or semi-cohesionless soil, pcf;
ϕ_s = Internal friction angle of cohesionless or semi-cohesionless soil, degree;
K_{oc} = Coefficient of at-rest earth pressure in cohesive soil;
K_{os} = Coefficient of at-rest earth pressure in cohesionless or semi-cohesionless soil;
γ_w = Unit weight of water, pcf;
q = Surcharge load at surface, psf;
P_o = Lateral pressure, psf;
P_i, P_{ic}, P_{is} = At-rest earth pressure, psf; i = 1, 2;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Height of wall, feet

LATERAL EARTH PRESSURE DIAGRAM FOR PERMANENT WALL

SUBMERGED COHESIVE SOIL OVER
COHESIONLESS OR SEMI-COHESIONLESS SOIL

Geotest Engineering, Inc.

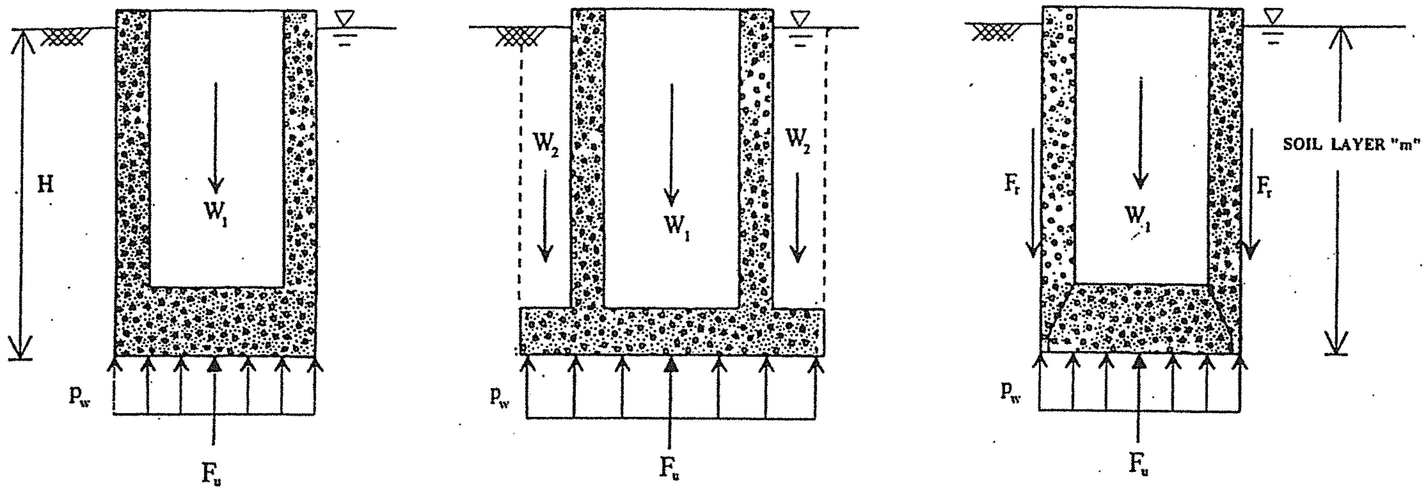
FIGURE 10.3

Job No. 1140193801

(a) DEAD WEIGHT OF STRUCTURE

(b) WEIGHT OF SOIL ABOVE BASE EXTENSION PLUS DEAD WEIGHT OF STRUCTURE

(c) SOIL-WALL FRICTION PLUS DEAD WEIGHT OF STRUCTURE



(a)

$$p_w = H\gamma_w$$

$$F_u = A_b p_w$$

$$\frac{W_1}{Sf_1} = F_u$$

(b)

$$p_w = H\gamma_w$$

$$F_u = A_b p_w$$

$$\frac{W_1}{Sf_1} + \frac{W_2}{Sf_2} = F_u$$

(c)

$$p_w = H\gamma_w$$

$$F_u = A_b p_w$$

$$\frac{W_1}{Sf_1} + \frac{F_r}{Sf_3} = F_u$$

Predominantly Cohesive Soils, $F_r = \alpha\, c_m A_m$

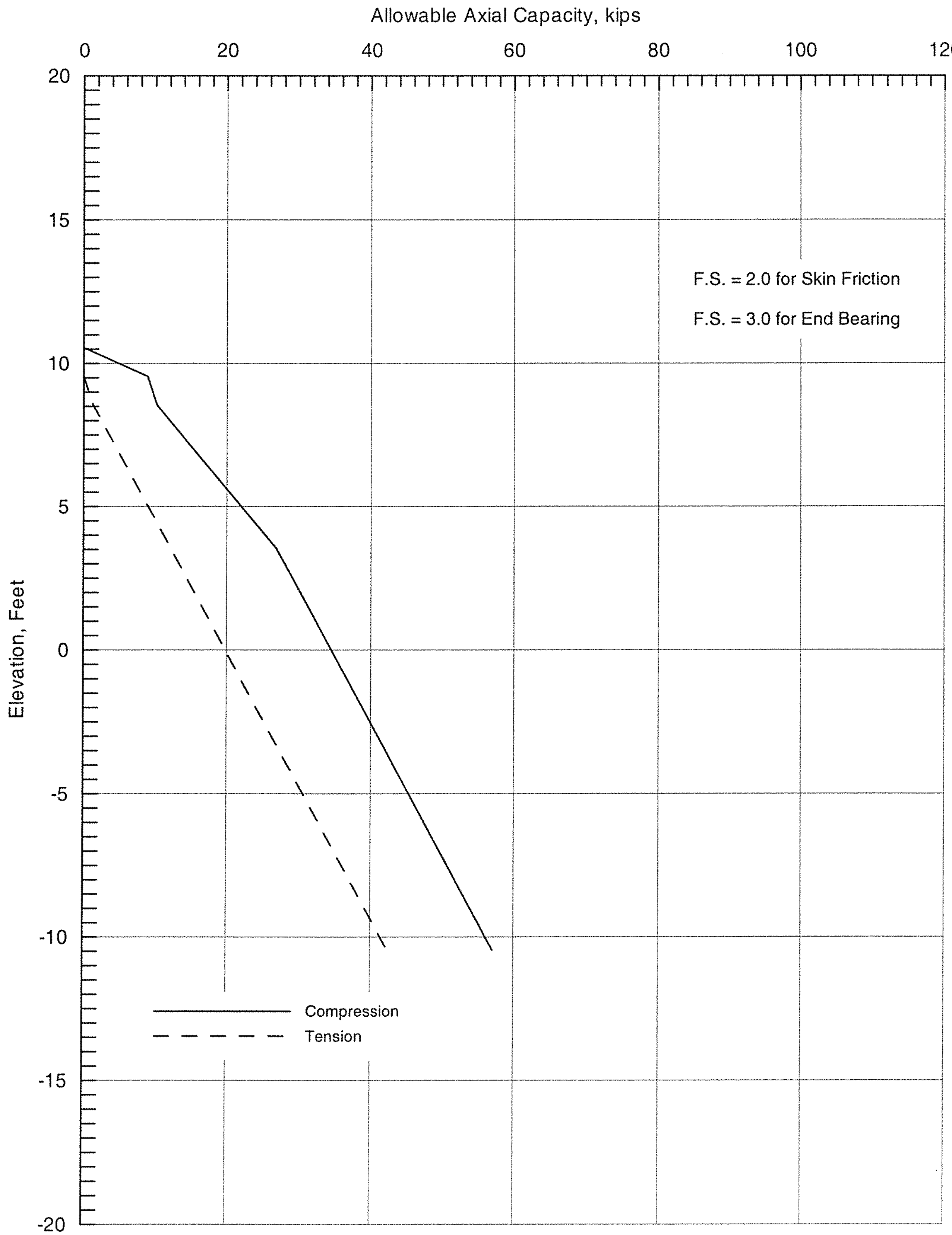
Predominantly Cohesionless Soils, $F_r = p_m A_m K \tan \delta_m$

See Table 2 for typical values of soil parameters

Where:

A_b	=	area of base, sq. ft.
A_m	=	cylindrical surface area of layer "m" , sq. ft.
c_m	=	undrained cohesion of soil layer "m", psf.
F_u	=	hydrostatic uplift force, lbs.
F_r	=	frictional resistance, lbs.
H	=	height of buried structure, ft.
K	=	coefficient of lateral pressure = 0.5.
p_m	=	average overburden pressure for layer "m," psf.
p_w	=	hydrostatic uplift pressure, psf.
$Sf_{1,\,2,\,3}$	=	factor of safety.
W_1	=	dead weight of concrete structure, lbs.
W_2	=	weight of backfill above base extension, lbs.
α	=	cohesion reduction factor = 0.5.
δ_m	=	friction angle between soil layer "m" and concrete wall, degrees = 0.75 ϕ_m
ϕ_m	=	internal angle of friction of soil layer "m", degrees.
γ_w	=	unit weight of water = 62.4 pcf.

UPLIFT PRESSURE AND RESISTANCE



ALLOWABLE AXIAL CAPACITY

30-INCH DIAMETER DRILLED SHAFT

PIPE SUPPORT AT LLPS NO. 2 AT EWPP

(BORINGS GLLP-4 AND GLLP-5)

FIGURE 12

TABLES

TABLE 1
SUMMARY OF FIELD EXPLORATION

Boring No.	Depth (feet)	Northing	Easting	Ground Surface Elevation
GLLP-1	50	13838135.06	3169162.79	8.78
GLLP-2	50	13837866.47	3169200.07	8.23
GLLP-3	25	13836996.15	3169449.86	17.55
GLLP-4 (GLLP-4P)	25	13836017.04	3169488.32	14.45
GLLP-5 (GLLP-5P)	25	13835878.08	3169488.32	14.66
GLLP-6A	25	13835336.89	3169536.00	14.96
GLLP-7 (GLLP-7P)	25	13835249.17	3169299.90	17.06

Note: The survey information of completed borings was provided to us by LAN.

TABLE 2

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION

Alignments	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, pcf	Submerged Unit Weight, γ', pcf	Undrained Cohesion, psf	Internal Friction Angle, ϕ, degree
84-inch	GLLP-1	Cohesive	0-9.5	120	60	1,000	--
		Cohesionless	9.5-12	114	52	--	30
		Cohesive	12-17	132	70	600	--
			17-22	135	72	2,000	--
			22-29	129	66	3,600	--
			29-34	131	69	2,000	--
			34-36	130	68	400	--
		Cohesionless	36-50	111	48	--	35
	GLLP-2	Cohesive Fill	0-10	126	63	1,000	--
		Cohesive	10-20	128	66	1,000	--
			20-38	132	69	3,000	--
			38-40	128	66	800	--
		Cohesionless	40-50	130	68	--	30
60-inch and 48-inch	GLLP-3	Cohesive	0-12	124	62	2,000	--
			12-25	121	59	1,600	--
	GLLP-4, GLLP-5, & GLLP-6A	Cohesive Fill	0-4 to 0-6	130	65	600	--
		Cohesive	6-25	130	68	1,000	--
	GLLP-7	Cohesive Fill	0-6	126	63	1,500	--
		Cohesive	6-10	126	63	1,200	--
		Cohesionless	10-12	105	43	--	25
		Cohesive	12-25	126	64	2,500	--

Notes:

1. Cohesive Fill includes Fat Clay, Fat Clay w/sand and Lean Clay w/grass roots and calcareous and ferrous nodules.
2. Cohesive soils include Sandy Lean Clay, Lean Clay w/sand, Fat Clay w/sand, Lean Clay and Fat Clay.
3. Cohesionless soils include Silt and Clayey Silt.

TABLE 3.1

GEOTECHNICAL DESIGN PARAMETER SUMMARY
TRENCHLESS INSTALLATION AT HUNTING BAYOU CROSSING
(Based on Borings GLLP-1 and GLLP-2)

PROPERTY		COHESIVE SOILS [1]	COHESIONLESS SOILS [2]
Wet Unit Weight, γ, pcf	0-10	124	--
	10-12	120 (GLLP-2 only)	114 (GLLP-1 only)
	12-17	130	--
	17-22	130	--
	22-29	129	--
	29-34	132	--
	34-36	131	--
	36-40	130	111 (GLLP-1 only)
	40-50	--	111
Submerged Unit Weight, γ', pcf	0-10	62	--
	10-12	58 (GLLP-2 only)	-- (GLPP-1 only)
	12-17	68	--
	17-22	68	--
	22-29	67	--
	29-34	70	--
	34-36	69	--
	36-40	68	48 (GLLP-1 only)
	40-50	--	48
Moisture Content (%)	0-10	23	--
	10-12	18 (GLLP-2 only)	21 (GLLP-1 only)
	12-17	18	--
	17-22	20	--
	22-29	18	--
	29-34	20	--
	34-36	26	--
	36-40	23	21 (GLLP-1 only)
	40-50	--	23
UNDRAINED PROPERTIES			
Undrained Cohesion, c_u, psf	29-34*	3,000	--
	34-36*	400	--
	36-40*	500 (GLLP-2 only)	--
	40-48*	--	--
Angle of Internal Friction, ϕ, degrees	29-34*	--	--
	34-36*	--	--
	36-40*	--	30 (GLLP-1 only)
	40-48*	--	35
Elastic Modulus, E, psf	29-34*	900,000	--
	34-36*	160,000	--
	36-40*	200,000	520,000 (GLLP-1 only)
	40-48*	--	600,000
Coefficient of Lateral Earth pressure at Rest, K_o,	29-34*	1.2	--
	34-36*	1.2	--
	36-40*	1.2	0.5 (GLLP-1 only)
	40-48*	--	0.43
Poisson's Ratio, μ		0.45	0.3
DRAINED PROPERTIES			
Drained Cohesion, c', psf	29-34*	0	--
	34-36*	0	--
	36-40*	0	--
	40-48*	0	--
Angle of Internal Friction, ϕ', degrees	29-34*	21	--
	34-36*	28	--
	36-40*	29	30 (GLLP-1 only)
	40-48*	--	35
Elastic Modulus, E, psf	29-34*	540,000	--
	34-36*	96,000	--
	36-40*	120,000	520,000 (GLLP-1 only)
	40-48*	--	600,000

Notes: 1. Cohesive soils include Fat Clay, Lean Clay, Lean Clay with sand and Sandy Lean Clay.
2. Cohesionless soils include Sandy Silt and Silty Sand.
* Tunnel zone which includes invert depth plus 6 feet above invert plus 6 feet below invert

TABLE 3.2

GEOTECHNICAL DESIGN PARAMETER SUMMARY
TRENCHLESS INSTALLATION – 48" WATER LINE CROSSING
54" PIPELINES NEAR STA. 7+80
(Based on Borings GLLP-6A)

PROPERTY		COHESIVE SOILS [1]
Wet Unit Weight, γ, pcf	0-4	123
	4-6	123
	6-14	127
	14-16	124
	16-18	124
	18-20	124
	20-25	124
Submerged Unit Weight, γ', pcf	0-4	62
	4-6	62
	6-14	65
	14-16	62
	16-18	62
	18-20	62
	20-25	62
Moisture Content (%)	0-4	24
	4-6	25
	6-14	23
	14-16	23
	16-18	21
	18-20	17
	20-25	15
UNDRAINED PROPERTIES		
Undrained Cohesion, c_u, psf	9-18*	1,200
	18-25*	900
Angle of Internal Friction, ϕ, degrees	9-18*	--
	18-25*	--
Elastic Modulus, E, psf	9-18*	360,000
	18-25*	360,000
Coefficient of Lateral Earth pressure at Rest, K_o,	9-18*	1.2
	18-25*	1.2
Poisson's Ratio, μ		0.45
DRAINED PROPERTIES		
Drained Cohesion, c', psf	9-18*	0
	18-25*	0
Angle of Internal Friction, ϕ', degrees	9-18*	22
	18-25*	29
Elastic Modulus, E, psf	9-18*	216,000
	18-25*	216,000

Notes: 1. Cohesive soils include Fat Clay, Lean Clay with sand and Sandy Lean Clay.
* Tunnel zone which includes invert depth plus 6 feet above invert plus 6 feet below invert

TABLE 3.3

GEOTECHNICAL DESIGN PARAMETER SUMMARY
TRENCHLESS INSTALLATION – 48" WATER LINE CROSSING
54" PIPELINES NEAR STA. 11+75
(Based on Boring GLLP-5)

PROPERTY		COHESIVE SOILS [1]
Wet Unit Weight, γ, pcf	0-6	138
	6-10	138
	10-16	121
	16-23	124
	23-25	124
Submerged Unit Weight, γ', pcf	0-6	76
	6-10	76
	10-16	59
	16-23	62
	23-25	62
Moisture Content (%)	0-6	25
	6-10	32
	10-16	27
	16-23	23
	23-25	16
UNDRAINED PROPERTIES		
Undrained Cohesion, c_u, psf	9-18*	1,500
	18-25*	1,000
Angle of Internal Friction, ϕ, degrees	9-18*	--
	18-25*	--
Elastic Modulus, E, psf	9-18*	450,000
	18-25*	400,000
Coefficient of Lateral Earth pressure at Rest, K_o,	9-18*	1.2
	18-25*	1.2
Poisson's Ratio, μ		0.45
DRAINED PROPERTIES		
Drained Cohesion, c', psf	9-18*	0
	18-25*	0
Angle of Internal Friction, ϕ', degrees	9-18*	22
	18-25*	25
Elastic Modulus, E, psf	9-18*	270,000
	18-25*	240,000

Notes: 1. Cohesive soils include Fat Clay, Fat Clay with sand, and Lean Clay with sand.
* Tunnel zone which includes invert depth plus 6 feet above invert plus 6 feet below invert

TABLE 4

SUMMARY OF SOIL PARAMETERS USED FOR DRILLED SHAFT ANALYSIS FOR PIPE SUPPORT

(Based on Borings GLLP-4 and GLLP-5)

Depth (feet)		Soil Type	Total Unit Weight (pcf)	Submerged Unit Weight (pcf)	Undrained Cohesion (psf)	Internal Friction Angle (degree)
From	To					
0	6	CLAY	130	65	600	--
6	16	CLAY	130	68	1,000	--
16	25	SANDY CLAY	130	68	1,000	--

APPENDIX A

LOG OF BORING NO. GLLP-1

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : N 13838135.06, E 3169162.79
See Plan of Borings (Figure 2)

COMPLETION DEPTH : 50.0 FT.

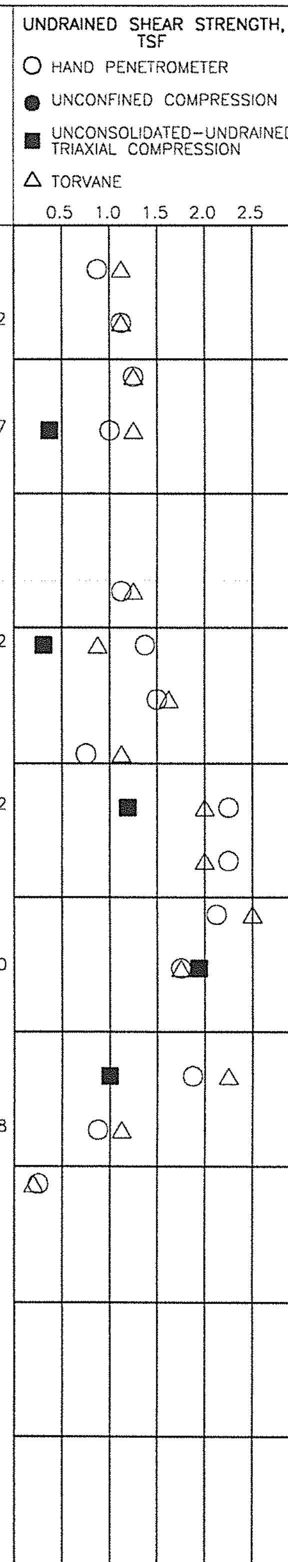
SURFACE ELEVATION : 8.78 FT.

DATE : 01-15-14

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 10.0 FT.
WET ROTARY : 10.0 TO 50.0 FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL
8.8	0	Stiff to very stiff gray and red FAT CLAY (CH) w/sand seams and calcareous nodules -very stiff 2'-6' -w/vertical sand seams 4'-6' -medium stiff to very stiff gray and red 6'-8'
-0.7		Medium dense gray SILTY SAND (SM)
-3.2		Very stiff brown and gray SANDY LEAN CLAY (CL) w/ferrous nodules and sand seams -medium stiff to very stiff 14'-16'
-8.2		Very stiff brown and gray FAT CLAY (CH) w/ferrous nodules and sand seams -stiff to very stiff 18'-20' -very stiff to hard 20'-22' -hard 22'-26' -reddish brown and gray 24'-26' -gray and red w/ferrous nodules and clay stone 28'-29'
-20.2		Gray and brown LEAN CLAY (CL) w/sand seams -very stiff to hard 30'-32' -stiff to very stiff 32'-34' -soft to medium stiff w/silt stone and calcareous nodules 34'-36'
-27.2		Very dense reddish brown SANDY SILT (ML) -w/gravel 40.5'-42'
-41.2	50	

STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
			21			
	96		24	68	26	42
			21			
	90	96	25	61	24	37
14	35		21			
			16			
	54	115	15	36	14	22
			20			
			20			
	89	114	18	54	22	32
			18			
			18			
	93	109	18	51	21	30
		111	18			
	96		22	37	19	18
			29			
90			22			
56	54		27			
100/6.0"			22			
83			23			
100/1.0"			23			



DEPTH TO WATER IN BORING :
▽: FREE WATER 1st ENCOUNTERED AT 10.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 6.6 FT.
HOLE OPEN TO 50.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

FIGURE A-1

LOG OF BORING NO. GLLP-2

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas
PROJECT NO. : 1140193801

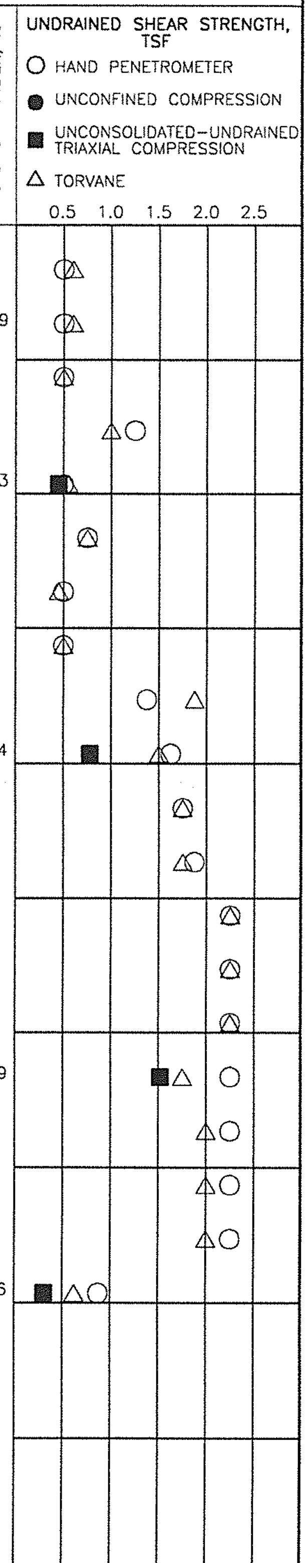
LOCATION : N 13837866.47, E 3169200.07 See Plan of Borings (Figure 2)
COMPLETION DEPTH : 50.0 FT.

SURFACE ELEVATION : 8.23 FT.
DATE : 11-04-13

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 14.0 FT.
WET ROTARY : 14.0 TO 50.0 FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
8.2	0	FILL: stiff yellowish brown and gray LEAN CLAY (CL) w/sand				17			
		-w/grass roots 0'-2'		77		21	46	17	29
	5	-w/calcareous nodules 0'-10'							
		-very stiff 6'-8'				16			
		-medium stiff to stiff				15			
		yellowish brown and dark gray fat clay w/sand partitions 8'-10'		78	104	22	53	20	33
-1.8	10	Stiff gray LEAN CLAY w/sand (CL)				18			
						20			
	15	-gray and brown w/ferrous nodules and ferrous stains 14'-16'				17			
-7.8		Very stiff gray and yellow FAT CLAY (CH) w/sand seams				19			
		-stiff to very stiff 18'-20'		89	107	20	57	23	34
	20	-w/calcareous nodules 20'-36'				21			
		-hard 24'-30'				21			
	25	-gray and red 26'-28'				16			
						18			
	30	-very stiff to hard, slickensided 30'-32'				19			
		-w/ferrous nodules 30'-34' -w/clay stone seams 30'-38' -hard 32'-38'		95	108	22	63	24	39
						22			
	35					20			
						21			
-29.8		Medium stiff to stiff reddish brown LEAN CLAY (CL)		95	104	23	35	19	16
-32.3	40	Dense reddish brown SILT (ML)	48			24			
	45	-w/clayey seams 43.5'-45'	41	93		21			
-41.8	50	-very dense 48.5'-50'	50			26			

UNDRAINED SHEAR STRENGTH, TSF



DEPTH TO WATER IN BORING :
∇: FREE WATER 1st ENCOUNTERED AT 14.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 7.0 FT.
HOLE OPEN TO 50.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

FIGURE A-2

LOG OF BORING NO. GLLP-3 (GLLP-3P)

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : N 13836996.15, E 3169449.86 See Plan of Borings (Figure 2)

COMPLETION DEPTH : 25.0 FT.

SURFACE ELEVATION : 17.55 FT.

DATE : 11-05-13

SAMPLER : Shelby Tube/Split Spoon

DRY AUGER : 0.0 TO 23.0 FT.

WET ROTARY : 23.0 TO 25.0 FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
17.6	0	Very stiff dark brown FAT CLAY (CH) w/sand seams -w/grass roots and calcareous nodules 0'-2'				38			
		-dark gray 2'-4' -yellow and gray 4'-12'		88		26	55	22	33
	5					26			
		-slickensided 6'-8' -w/ferrous nodules 6'-20' -w/ferrous stains 6'-25'		94	97	28	78	28	50
	10					36			
		-stiff to very stiff 12'-14'				34			
		-yellowish brown and gray 12'-18'		99	92	31	76	28	48
	15					32			
		-brown and gray 18'-25'				26			
	20					23			
		-stiff to very stiff 23'-25'							
-7.4	25					24			

NOTE : See Piezometer GLLP-3P for water level measurements.

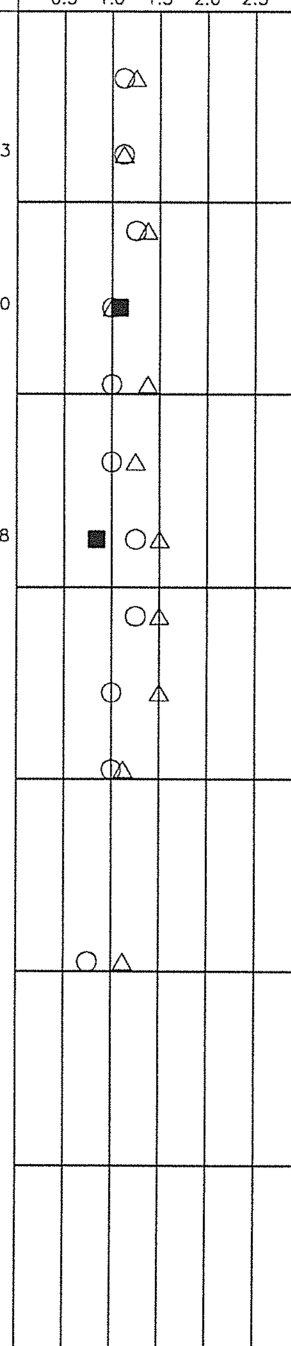
UNDRAINED SHEAR STRENGTH, TSF

○ HAND PENETROMETER

● UNCONFINED COMPRESSION

■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION

△ TORVANE



DEPTH TO WATER IN BORING :

▽: FREE WATER 1st ENCOUNTERED AT 23.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 11.2 FT.

▼: WATER DEPTH AT 7.6 FT., HOLE OPEN TO 25.0 FT. ON 01-24-14.

Geotest Engineering, Inc.

FIGURE A-3

LOG OF BORING NO. GLLP-4

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : N 13836017.04, E 3169488.32 See Plan of Borings (Figure 2)

COMPLETION DEPTH : 25.0 FT.

SURFACE ELEVATION : 14.45 FT.

DATE : 11-05-13

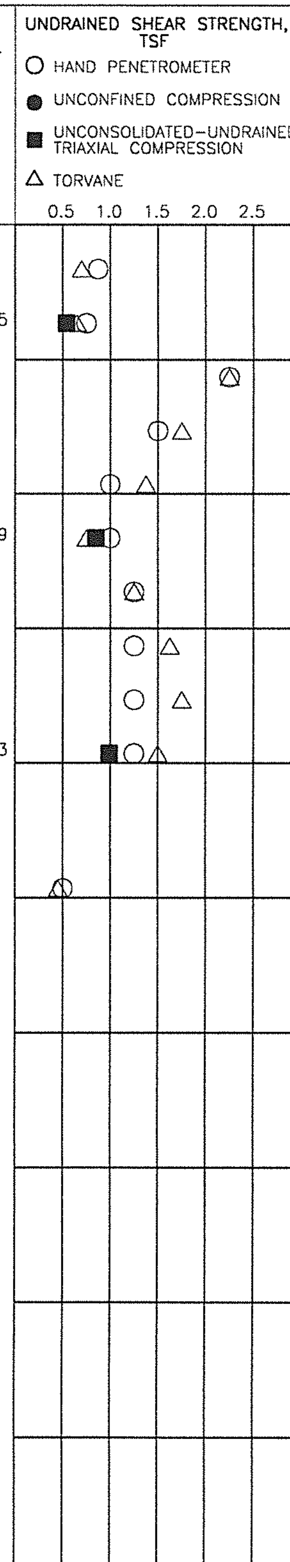
SAMPLER : Shelby Tube/Split Spoon

DRY AUGER : 0.0 TO 23.0 FT.

WET ROTARY : 23.0 TO 25.0 FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
14.5	0	FILL: stiff dark gray fat clay w/sand and calcareous nodules -w/grass roots 0'-2' -yellow and gray 2'-4' -hard dark gray, brown and yellow 4'-6'				21			
				70	106	22	56	21	35
	5					15			
8.5		Very stiff gray and brown FAT CLAY (CH) w/sand seams -stiff to very stiff, slickensided 10'-12' -w/ferrous nodules and ferrous stains 10'-16'				22			
						23			
	10			89	102	25	50	21	29
						22			
	15					21			
-1.5		Very stiff brown SANDY LEAN CLAY (CL) w/calcareous and ferrous nodules and ferrous stains				19			
	20			68	111	18	41	18	23
		-medium stiff to stiff very sandy clay 23'-25'				21			
-10.5	25								

UNDRAINED SHEAR STRENGTH, TSF



DEPTH TO WATER IN BORING :
∇: FREE WATER 1st ENCOUNTERED AT 23.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 11.5 FT.
HOLE OPEN TO 25.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

FIGURE A-4

LOG OF BORING NO. GLLP-5 (GLLP-5P)

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : N 13835878.08, E 3169488.32 See Plan of Borings (Figure 2)

COMPLETION DEPTH : 25.0 FT.

SURFACE ELEVATION : 14.66 FT.

DATE : 11-04-13

SAMPLER : Shelby Tube/Split Spoon

DRY AUGER : 0.0 TO 12.0 FT.

WET ROTARY : 12.0 TO 25.0 FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL
14.7	0	FILL: medium stiff to stiff yellow and gray fat clay w/grass roots and sand –dark gray and brown 4'–6'
8.7		Stiff gray FAT CLAY (CH) w/ferrous nodules, ferrous stains and sand seams –brown and gray 8'–18' –slickensided10'–12' –very stiff 12'–18'
–3.3		Stiff gray and brown LEAN CLAY (CL) w/sand –very stiff w/calcareous nodules 23'–25'
–10.3	25	

NOTE :
See Piezometer GLLP-5P for water level measurements.

STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
			23			
			25			
	82	110	26	65	25	40
			29			
			34			
		93	30	72	27	45
			28			
			22			
			23			
	78	102	22	49	21	28
			16			

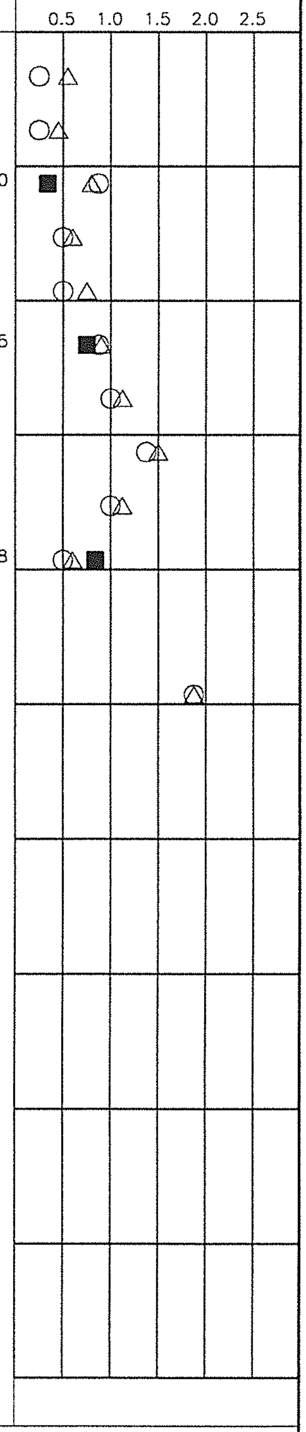
UNDRAINED SHEAR STRENGTH, TSF

○ HAND PENETROMETER

● UNCONFINED COMPRESSION

■ UNCONSOLIDATED–UNDRAINED TRIAXIAL COMPRESSION

△ TORVANE



DEPTH TO WATER IN BORING :

▽: FREE WATER 1st ENCOUNTERED AT 12.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 4.8 FT.

▼: WATER DEPTH AT 4.2 FT., HOLE OPEN TO 25.0 FT. ON 12-05-13.

Geotest Engineering, Inc.

FIGURE A–5

LOG OF BORING NO. GLLP-6

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : See Plan of Borings (Figure 2)

COMPLETION DEPTH : 2.0 FT.

SURFACE ELEVATION : Existing Grade

DATE : 11-05-13

SAMPLER : Shelby Tube/Split Spoon

DRY AUGER : 0.0 TO 2.0 FT.

WET ROTARY : -- TO -- FT.

ELEVATION, FEET	DEPTH, FEET	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, TSF
	0			Dark gray CLAY (CH) w/sand								○
				NOTE : Hit obstruction at 2' and offset to boring to boring GLLP-6A								

UNDRAINED SHEAR STRENGTH, TSF: ○ HAND PENETROMETER; ● UNCONFINED COMPRESSION; ■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION; △ TORVANE

Scale: 0.5 1.0 1.5 2.0 2.5

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

DEPTH TO WATER IN BORING :
NO GROUNDWATER ENCOUNTERED DURING DRILLING.
HOLE OPEN TO 2.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

LOG OF BORING NO. GLLP-6A

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : N 13835336.89, E 3169536.00
See Plan of Borings (Figure 2)

COMPLETION DEPTH : 25.0 FT.

SURFACE ELEVATION : 14.96 FT.

DATE : 11-06-13

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 16.0 FT.
WET ROTARY : 16.0 TO 25.0 FT.

ELEVATION, FEET: 15.0, 13.1, 11.0, -3.0, -10.0

DEPTH, FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

DESCRIPTION OF MATERIAL

8.5" Concrete over 2" Compacted Sand over 5" Dark Gray Clay over 1" Compacted Sand over 6" Concrete

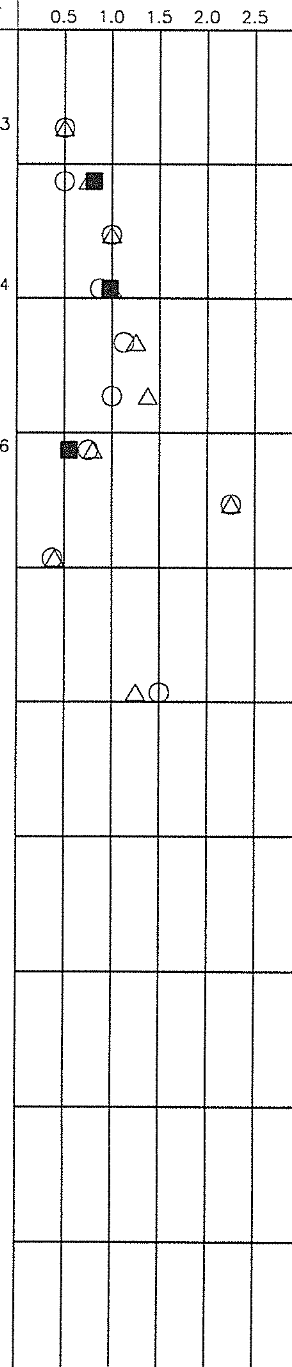
FILL: stiff gray, brown and dark gray sandy lean clay w/gras

Stiff dark gray FAT CLAY (CH) w/sand, ferrous nodules and ferrous stains
-very stiff 6'-8'
-yellowish brown and gray 6'-14'
-stiff to very stiff 8'-10'
-very stiff 10'-14'
-brown and gray 12'-14'
-gray and reddish brown w/silt layers 14'-18'
-hard 16'-18'

Medium stiff gray LEAN CLAY (CL) w/sand
-very stiff gray and brown 23'-25'

STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	60		22	43	20	23
		98	25			
			24			
	84	104	22	56	22	34
			21			
			24			
	84	101	23	60	24	36
			21			
			17			
			15			

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE



DEPTH TO WATER IN BORING :
▽: FREE WATER 1st ENCOUNTERED AT 16.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 9.4 FT.
HOLE OPEN TO 25.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

LOG OF BORING NO. GLLP-7 (GLLP-7P)

PROJECT : SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NO. : 1140193801

LOCATION : N 13835249.17, E 3169299.90
See Plan of Borings (Figure 2)

COMPLETION DEPTH : 25.0 FT.

SURFACE ELEVATION : 17.06 FT.

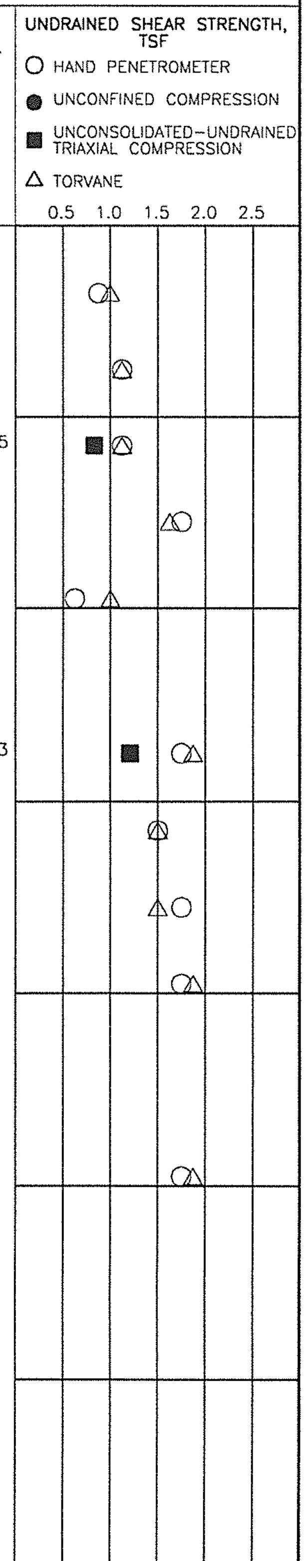
DATE : 11-05-13

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 12.0 FT.
WET ROTARY : 12.0 TO 25.0 FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL
17.1	0	FILL: stiff to very stiff dark gray fat clay w/sand seams –very stiff 2'–4' –brown and gray 2'–6'
11.1	6	Very stiff reddish brown FAT CLAY (CH) w/calcareous and ferr
9.1	8	Stiff to very stiff reddish brown LEAN CLAY (CL) w/silt and sand seams
7.1	10	Reddish brown CLAYEY SILT (ML)
5.1	12	Very stiff reddish brown FAT CLAY (CH) w/silt seams –lean clay w/silt layers 15'–17'
–7.9	25	

NOTE :
See Piezometer GLLP-7P for water level measurements.

STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
			24			
			23			
	94	103	22	58	23	35
			25			
			18			
			22			
	99	100	26	69	26	43
			26			
			26			
			26			
			24			



DEPTH TO WATER IN BORING :
▽: FREE WATER 1st ENCOUNTERED AT 11.0 FT. DURING DRILLING;
▼: WATER DEPTH AT 13.3 FT., HOLE OPEN TO 25.0 FT. ON 01-24-14.

Geotest Engineering, Inc.

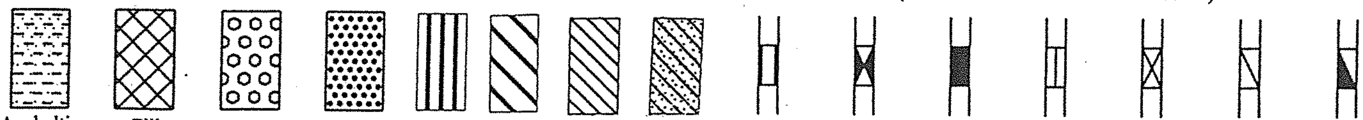
FIGURE A-7

Job No. 1140193801

SYMBOLS AND TERMS USED ON BORING LOGS

SOIL TYPES
(SHOWN IN SYMBOL COLUMN)

SAMPLER TYPES
(SHOWN IN SAMPLES COLUMN)



Asphaltic Concrete | Fill | Gravel | Sand | SILT | CLAY | LEAN CLAY | Sandy LEAN CLAY | Pitcher Barrel | Nx Core | Shelby Tube | Piston | Split Spoon | No Recovery | Auger

Predominant type shown heavy

TERMS DESCRIBING CONSISTENCY OR CONDITION

Basic Soil Type	Density or Consistency	Standard Penetration Resistance, (1) Blows/ft.	Unconfined Compressive Strength (q_u), (2) Tons/sq. ft.
Cohesionless	Very loose	Less than 4	Not applicable
	Loose	4 to <10	Not applicable
	Medium dense	10 to <30	Not applicable
	Dense	30 to <50	Not applicable
	Very dense	50 or greater	Not applicable
Cohesive	Very soft	Less than 2	Less than 0.25
	Soft	2 to <4	0.25 to <0.5
	Firm/Medium stiff	4 to <8	0.5 to <1.0
	Stiff	8 to <15	1.0 to <2.0
	Very stiff	15 to <30	2.0 to <4.0
	Hard	30 or greater	4 or greater

(1) Number of blows from 140-lb. weight falling 30-in. to drive 2-in. OD, 1-3/8-in. ID, split barrel sampler (ASTM D1586)

(2) q_u may also be approximated using a pocket penetrometer

TERMS CHARACTERIZING SOIL STRUCTURE

Parting: -paper thin in size | Seam: -1/8" to 3" thick | Layer: -greater than 3"

Slickensided	- having inclined planes of weakness that are slick and glossy in appearance.
Fissured	- containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated	- composed of thin layers of varying color and texture.
Interbedded	- composed of alternate layers of different soil types.
Calcareous	- containing appreciable quantities of calcium carbonate.
Well graded	- having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly graded	- predominantly of one grain size, or having a range of sizes with some intermediate size missing.
Flocculated	- pertaining to cohesive soils that exhibit a loose knit or flakey structure.

APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection
and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas

PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE				SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST	TRIAXIAL COMPRESSION TEST (U-U)		TORVANE	POCKET PENE-TROMETER	TYPE OF MATERIAL
	No.	Depth (ft.) Top	Depth (ft.) Bottom	Type				LL	PL	PI		Shear Strength (tsf)	Shear Strength (tsf)	Conf. Press. (tsf)	Shear Strength (tsf)	Shear Strength (tsf)	
GLLP-1	1	0.0	2.0	UD		21									1.13	0.88	Fat Clay
	2	2.0	4.0	UD		24		68	26	42	96				1.13	1.13	Fat Clay
	3	4.0	6.0	UD		21									1.25	1.25	Fat Clay
	4	6.0	8.0	UD		25	96	61	24	37	90		0.37	0.58	1.25	1.00	Fat Clay
	6	10.5	12.0	SS	14	21					35						Silty Sand
	7	12.0	14.0	UD		16									1.25	1.13	Sandy Lean Clay
	8	14.0	16.0	UD		15	115	36	14	22	54		0.31	1.15	0.88	1.38	Sandy Lean Clay
	9	16.0	18.0	UD		20									1.63	1.50	Fat Clay
	10	18.0	20.0	UD		20									1.13	0.75	Fat Clay
	11	20.0	22.0	UD		18	114	54	22	32	89		1.19	1.58	2.00	2.25	Fat Clay
	12	22.0	24.0	UD		18									2.00	2.25	Fat Clay
	13	24.0	26.0	UD		18									2.50	2.13	Fat Clay
	14	26.0	28.0	UD		18	109	51	21	30	93		1.94	2.02	1.75	1.75	Fat Clay
	16	30.0	32.0	UD		18	111						1.00	2.30	2.25	1.88	Lean Clay
	17	32.0	34.0	UD		22		37	19	18	96				1.13	0.88	Lean Clay
	18	34.0	36.0	UD		29									0.20	0.25	Lean Clay
	19	36.5	38.0	SS	90	22											Sandy Silt
	20	38.5	40.0	SS	56	27					54						Sandy Silt
	21	40.5	42.0	SS	100/6.0"	22											Sandy Silt
	22	43.5	45.0	SS	83	23											Sandy Silt
	23	48.5	50.0	SS	100/1.0"	23											Sandy Silt

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-1

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas
PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE No.	Depth (ft.) Top	Depth (ft.) Bottom	Type	SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL	PL	PI	PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Shear Strength (tsf)	Conf. Press. (tsf)	TORVANE Shear Strength (tsf)	POCKET PENE-TROMETER Shear Strength (tsf)	TYPE OF MATERIAL
GLLP-2	1	0.0	2.0	UD		17									0.60	0.50	Fill
	2	2.0	4.0	UD		21		46	17	29	77				0.60	0.50	Fill
	3	4.0	6.0	UD		16									0.50	0.50	Fill
	4	6.0	8.0	UD		15									1.00	1.25	Fill
	5	8.0	10.0	UD		22	104	53	20	33	78		0.45	0.72	0.55	0.50	Fill
	6	10.0	12.0	UD		18									0.75	0.75	Lean Clay
	7	12.0	14.0	UD		20									0.45	0.50	Lean Clay
	8	14.0	16.0	UD		17									0.50	0.50	Lean Clay
	9	16.0	18.0	UD		19									1.88	1.38	Fat Clay
	10	18.0	20.0	UD		20	107	57	23	34	89		0.78	1.44	1.50	1.63	Fat Clay
	11	20.0	22.0	UD		21									1.75	1.75	Fat Clay
	12	22.0	24.0	UD		21									1.75	1.88	Fat Clay
	13	24.0	26.0	UD		16									2.25	2.25	Fat Clay
	14	26.0	28.0	UD		18									2.25	2.25	Fat Clay
	15	28.0	30.0	UD		19									2.25	2.25	Fat Clay
	16	30.0	32.0	UD		22	108	63	24	39	95		1.52	2.30	1.75	2.25	Fat Clay
	17	32.0	34.0	UD		22									2.00	2.25	Fat Clay
	18	34.0	36.0	UD		20									2.00	2.25	Fat Clay
	19	36.0	38.0	UD		21									2.00	2.25	Fat Clay
	20	38.0	40.0	UD		23	104	35	19	16	95		0.31	2.88	0.63	0.88	Lean Clay
	21	40.5	42.0	SS	48	24											Silt

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-2

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas

PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE No.	SAMPLE Depth (ft.) Top	SAMPLE Depth (ft.) Bottom	SAMPLE Type	SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PL	ATTERBERG LIMITS PI	PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Conf. Press. (tsf)	TORVANE Shear Strength (tsf)	POCKET PENE-TROMETER Shear Strength (tsf)	TYPE OF MATERIAL
GLLP-2	22	43.5	45.0	SS	41	21					93						Silt
	23	48.5	50.0	SS	50	26											Silt

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-2a

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas

PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE				SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST	TRIAXIAL COMPRESSION TEST (U-U)		TORVANE	POCKET PENE-TROMETER	TYPE OF MATERIAL
	No.	Depth (ft.) Top	Depth (ft.) Bottom	Type				LL	PL	PI		Shear Strength (tsf)	Shear Strength (tsf)	Conf. Press. (tsf)	Shear Strength (tsf)	Shear Strength (tsf)	
GLLP-3 (GLLP-3P)	1	0.0	2.0	UD		38									1.25	1.13	Fat Clay
	2	2.0	4.0	UD		26		55	22	33	88				1.13	1.13	Fat Clay
	3	4.0	6.0	UD		26									1.38	1.25	Fat Clay
	4	6.0	8.0	UD		28	97	78	28	50	94		1.08	0.58	1.00	1.00	Fat Clay
	5	8.0	10.0	UD		36									1.38	1.00	Fat Clay
	6	10.0	12.0	UD		34									1.25	1.00	Fat Clay
	7	12.0	14.0	UD		31	92	76	28	48	99		0.84	1.01	1.50	1.25	Fat Clay
	8	14.0	16.0	UD		32									1.50	1.25	Fat Clay
	9	16.0	18.0	UD		26									1.50	1.00	Fat Clay
	10	18.0	20.0	UD		23									1.13	1.00	Fat Clay
	11	23.0	25.0	UD		24									1.13	0.75	Fat Clay

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-3

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas

PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE				SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST	TRIAXIAL COMPRESSION TEST (U-U)		TORVANE	POCKET PENE-TROMETER	TYPE OF MATERIAL
	No.	Depth (ft.) Top	Depth (ft.) Bottom	Type				LL	PL	PI		Shear Strength (tsf)	Shear Strength (tsf)	Conf. Press. (tsf)	Shear Strength (tsf)	Shear Strength (tsf)	
GLLP-4	1	0.0	2.0	UD		21									0.70	0.88	Fill
	2	2.0	4.0	UD		22	106	56	21	35	70		0.54	0.29	0.65	0.75	Fill
	3	4.0	6.0	UD		15									2.25	2.25	Fill
	4	6.0	8.0	UD		22									1.75	1.50	Fat Clay
	5	8.0	10.0	UD		23									1.38	1.00	Fat Clay
	6	10.0	12.0	UD		25	102	50	21	29	89		0.85	0.86	0.75	1.00	Fat Clay
	7	12.0	14.0	UD		22									1.25	1.25	Fat Clay
	8	14.0	16.0	UD		21									1.63	1.25	Fat Clay
	9	16.0	18.0	UD		19									1.75	1.25	Sandy Lean Clay
	10	18.0	20.0	UD		18	111	41	18	23	68		0.99	1.44	1.50	1.25	Sandy Lean Clay
	11	23.0	25.0	UD		21									0.45	0.50	Sandy Lean Clay

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-4

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE No.	SAMPLE Depth (ft.) Top	SAMPLE Depth (ft.) Bottom	SAMPLE Type	SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PL	ATTERBERG LIMITS PI	PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Conf. Press. (tsf)	TORVANE Shear Strength (tsf)	POCKET PENE-TROMETER Shear Strength (tsf)	TYPE OF MATERIAL
GLLP-5 (GLLP-5P)	1	0.0	2.0	UD		23									0.55	0.25	Fill
	2	2.0	4.0	UD		25									0.45	0.25	Fill
	3	4.0	6.0	UD		26	110	65	25	40	82		0.34	0.43	0.80	0.88	Fill
	4	6.0	8.0	UD		29									0.60	0.50	Fat Clay
	5	8.0	10.0	UD		34									0.75	0.50	Fat Clay
	6	10.0	12.0	UD		30	93	72	27	45			0.75	0.86	0.90	0.88	Fat Clay
	7	12.0	14.0	UD		28									1.13	1.00	Fat Clay
	8	14.0	16.0	UD		22									1.50	1.38	Fat Clay
	9	16.0	18.0	UD		23									1.13	1.00	Fat Clay
	10	18.0	20.0	UD		22	102	49	21	28	78		0.84	1.44	0.60	0.50	Lean Clay
	11	23.0	25.0	UD		16									1.88	1.88	Lean Clay

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-5

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP WBS No. S-000900-0133-3; Houston, Texas

PROJECT NUMBER: 1140193801

BORING NO.	SAMPLE No.	SAMPLE Depth (ft.) Top	SAMPLE Depth (ft.) Bottom	SAMPLE Type	SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PL	ATTERBERG LIMITS PI	PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Conf. Press. (tsf)	TORVANE Shear Strength (tsf)	POCKET PENE-TROMETER Shear Strength (tsf)	TYPE OF MATERIAL
GLLP-6A	2	1.9	4.0	UD		22		43	20	23	60				0.50	0.50	Fill
	3	4.0	6.0	UD		25	98						0.81	0.43	0.75	0.50	Fat Clay
	4	6.0	8.0	UD		24									1.00	1.00	Fat Clay
	5	8.0	10.0	UD		22	104	56	22	34	84		0.98	0.72	1.00	0.88	Fat Clay
	6	10.0	12.0	UD		21									1.25	1.13	Fat Clay
	7	12.0	14.0	UD		24									1.38	1.00	Fat Clay
	8	14.0	16.0	UD		23	101	60	24	36	84		0.55	1.15	0.80	0.75	Fat Clay
	9	16.0	18.0	UD		21									2.25	2.25	Fat Clay
	10	18.0	20.0	UD		17									0.40	0.38	Lean Clay
	11	23.0	25.0	UD		15									1.25	1.50	Lean Clay

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-6A

SUMMARY OF LABORATORY TEST RESULTS

GEOTEST ENGINEERING, INC.

PROJECT NAME: SWTP – Low Lift Pump Station (LLPS) Direct Connection and Pressure Regulating Station (PRS) at EWPP
WBS No. S-000900-0133-3; Houston, Texas
PROJECT NUMBER: 1140193801

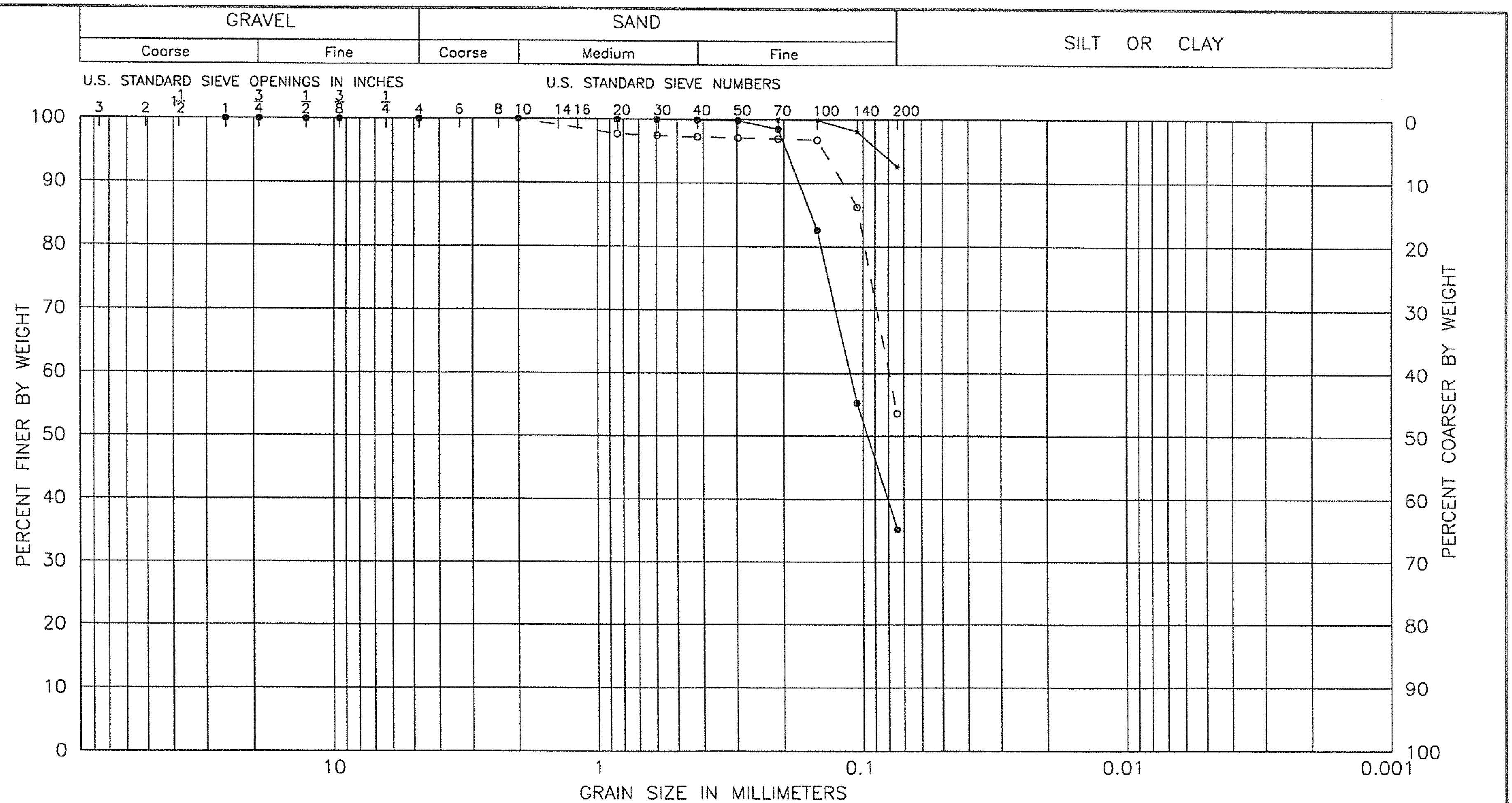
BORING NO.	SAMPLE No.	SAMPLE Depth (ft.) Top	SAMPLE Depth (ft.) Bottom	SAMPLE Type	SPT (blows/ft.)	WATER CONTENT (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PL	ATTERBERG LIMITS PI	PASSING NO. 200 SIEVE (%)	UNCONFINED COMPRESSION TEST Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Shear Strength (tsf)	TRIAXIAL COMPRESSION TEST (U-U) Conf. Press. (tsf)	TORVANE Shear Strength (tsf)	POCKET PENE-TROMETER Shear Strength (tsf)	TYPE OF MATERIAL
GLLP-7 (GLLP-7P)	1	0.0	2.0	UD		24									1.00	0.88	Fill
	2	2.0	4.0	UD		23									1.13	1.13	Fill
	3	4.0	6.0	UD		22	103	58	23	35	94		0.83	0.43	1.13	1.13	Fill
	4	6.0	8.0	UD		25									1.63	1.75	Fat Clay
	5	8.0	10.0	UD		18									1.00	0.63	Lean Clay
	6	10.0	12.0	UD		22											Clayey Silt
	7	12.0	14.0	UD		26	100	69	26	43	99		1.21	1.01	1.88	1.75	Fat Clay
	8	14.0	16.0	UD		26									1.50	1.50	Fat Clay
	9	16.0	18.0	UD		26									1.50	1.75	Fat Clay
	10	18.0	20.0	UD		26									1.88	1.75	Fat Clay
	11	23.0	25.0	UD		24									1.88	1.75	Fat Clay

LEGEND:
UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD
SS = SPLIT SPOON SAMPLE
AG = AUGER CUTTINGS
PB = PITCHER BARREL SAMPLE
Nx = Nx-DOUBBLE BARREL SAMPLE

SPT = Standard Penetration Test
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

FIGURE B-7

Job No. 1140193801



LEGEND	BORING NO.	SAMPLE NO.	DEPTH FT.	SAMPLE DESCRIPTION
●-●-●-●	GLLP-1	S-6	10.5-12.0	Gray silty sand
o-o-o-o	GLLP-1	S-20	38.5-40.0	Reddish brown sandy silt
×-×-×-×	GLLP-2	S-22	43.5-45.0	Reddish brown silt w/clayey seams

GRAIN SIZE DISTRIBUTION CURVES

Geotest Engineering, Inc.

FIGURE B-8

APPENDIX C

Job No. 1140193801

PIEZOMETER INSTALLATION REPORT

PROJECT NAME: SWTP – LOW LIFT PUMP STATION (LLPS) DIRECT CONENCTION AND PRESSURE REGULATING STATION (PRS) AT EWPP		PIEZOMETER NUMBER: GLLP–3P
GEOTECHNICAL CONSULTANT GEOTEST ENGINEERING, INC.	DESIGN CONSULTANT LAN, INC.	HOUSTON, TEXAS

COMPLETION DATE: 12–26–13

DRY AUGERED 0.0 TO 25.0 FT

WASH BORED –– TO –– FT

DRILLING FLUID: WATER

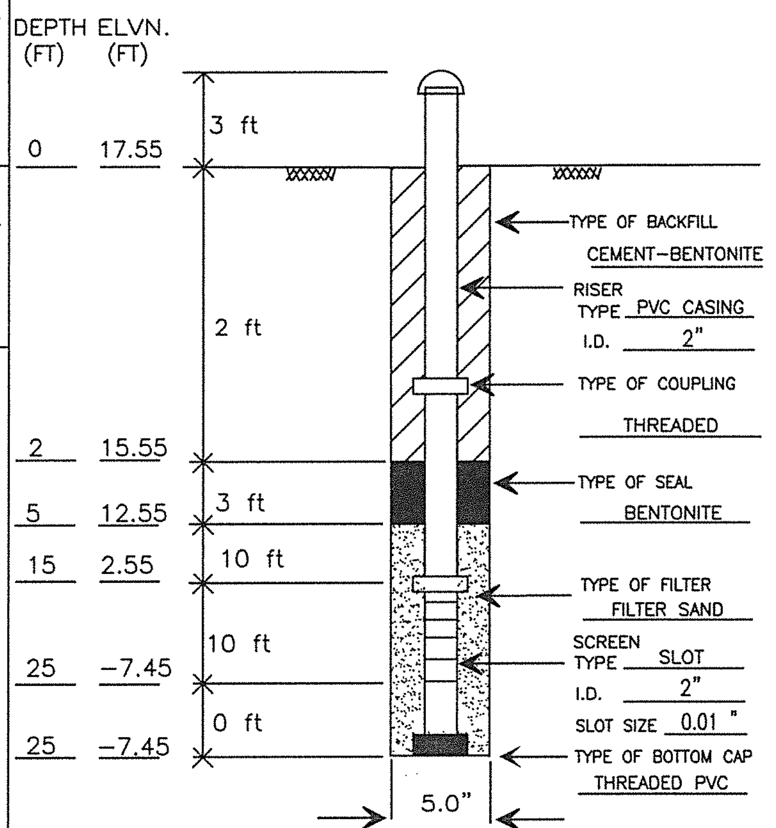
DEVELOPMENT DATE: 12–26–13

METHOD OF DEVELOPMENT:

BAILING

WATER LEVEL READINGS:

DATE	DEPTH (TOG)	ELEVATION
12–27–13	9.2	8.3
01–24–14	10.0	7.6



(NOT TO SCALE)

REMARKS:

NOTES: 1. DIMENSIONS NOMINAL UNLESS OTHERWISE NOTED 2. TOG = TOP OF GROUND	DRILLED BY: DG	STARTED: 12–26–13	NORTHING: 13836996.15 EASTING: 3169449.86
	LOGGED BY: TM	COMPLETED: 12–26–13	GROUND LEVEL (MSL), FT : 17.55
	CHECKED BY: NK	APPROVED BY: MB	SHEET 1 OF 1

GEOTEST ENGINEERING, INC.

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FIGURE C–1

Job No. 1140193801

PIEZOMETER INSTALLATION REPORT

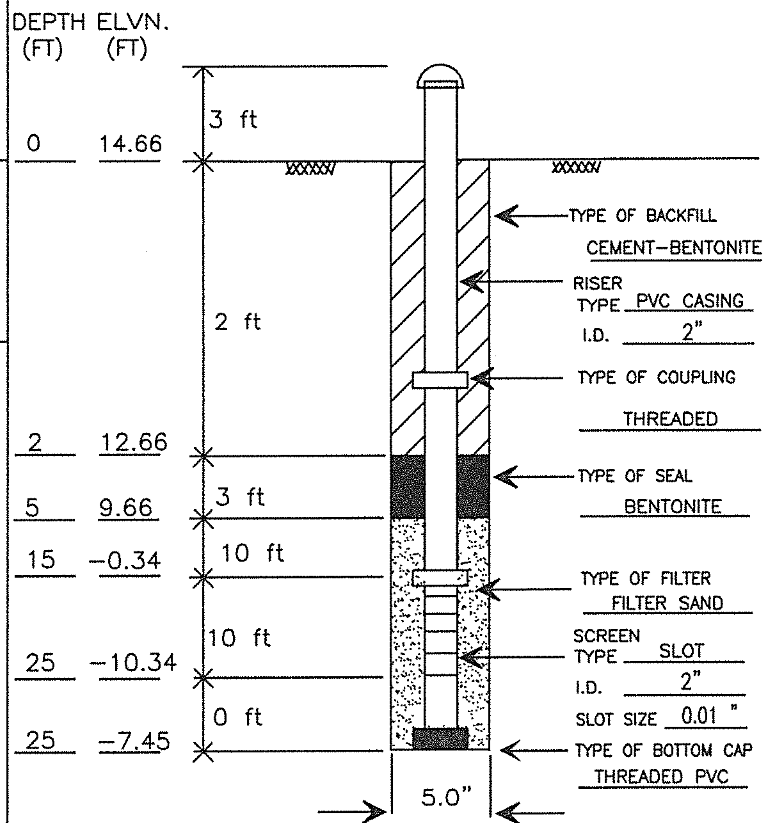
PROJECT NAME: SWTP – LOW LIFT PUMP STATION (LLPS) DIRECT CONENCTION AND PRESSURE REGULATING STATION (PRS) AT EWPP		PIEZOMETER NUMBER: GLLP–5P
GEOTECHNICAL CONSULTANT: GEOTEST ENGINEERING, INC.	DESIGN CONSULTANT: LAN, INC.	HOUSTON, TEXAS

COMPLETION DATE: 11–04–13
DRY AUGERED 0.0 TO 12.0 FT
WASH BORED 12.0 TO 25.0 FT
DRILLING FLUID: WATER

DEVELOPMENT DATE: 11–04–13
METHOD OF DEVELOPMENT:
BAILING

WATER LEVEL READINGS:

DATE	DEPTH (TOG)	ELEVATION
11–05–13	2.0	12.7
12–05–13	4.2	10.5



(NOT TO SCALE)

REMARKS:

NOTES:
1. DIMENSIONS NOMINAL UNLESS OTHERWISE NOTED
2. TOG = TOP OF GROUND

DRILLED BY: DG	STARTED: 11–04–13	NORTHING: 13835878.08 EASTING: 3169488.32
LOGGED BY: TM	COMPLETED: 11–04–13	GROUND LEVEL (MSL), FT : 14.66
CHECKED BY: NK	APPROVED BY: MB	SHEET 1 OF 1

GEOTEST ENGINEERING, INC.

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FIGURE C–2

Job No. 1140193801

PIEZOMETER INSTALLATION REPORT

PROJECT NAME: SWTP – LOW LIFT PUMP STATION (LLPS) DIRECT CONENCTION AND PRESSURE REGULATING STATION (PRS) AT EWPP		PIEZOMETER NUMBER: GLLP–7P
GEOTECHNICAL CONSULTANT: GEOTEST ENGINEERING, INC.	DESIGN CONSULTANT: LAN, INC.	HOUSTON, TEXAS

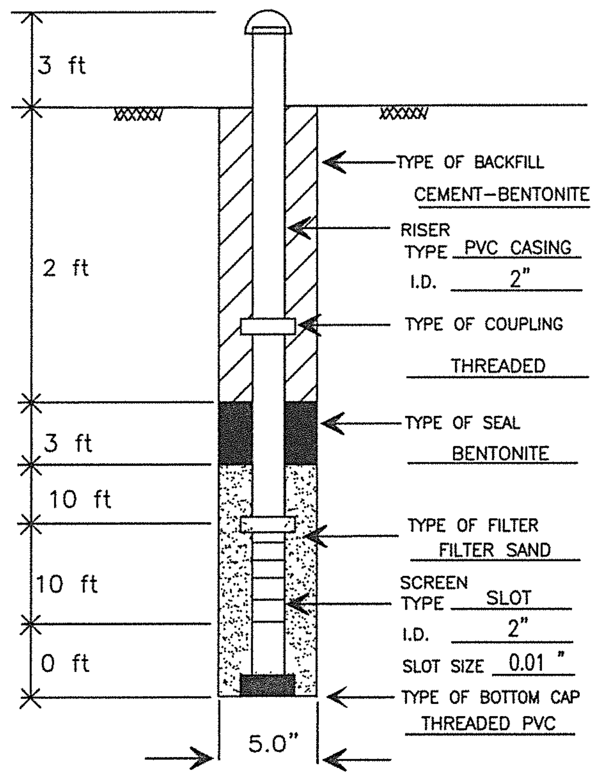
COMPLETION DATE: 12–26–13
DRY AUGERED 0.0 TO 25.0 FT
WASH BORED -- TO -- FT
DRILLING FLUID: WATER

DEVELOPMENT DATE: 12–26–13
METHOD OF DEVELOPMENT: BAILING

WATER LEVEL READINGS:

DATE	DEPTH (TOG)	ELEVATION
12–27–13	3.7	13.4
01–24–14	3.8	13.3

DEPTH (FT)	ELVN. (FT)
0	17.06
2	15.06
5	12.06
15	2.06
25	–7.94
25	–7.94



(NOT TO SCALE)

REMARKS:

NOTES:
1. DIMENSIONS NOMINAL UNLESS OTHERWISE NOTED
2. TOG = TOP OF GROUND

DRILLED BY: DG	STARTED: 12–26–13	NORTHING: 13835249.17 EASTING: 3169299.90
LOGGED BY: TM	COMPLETED: 12–26–13	GROUND LEVEL (MSL), FT : 17.06
CHECKED BY: NK	APPROVED BY: MB	SHEET 1 OF 1

APPENDIX D

APPENDIX D

Design Example 1

Given: Determine the bracing pressures by using the formulas provided in Figure 5.1 assuming the following:

- Assume excavation is 20-ft deep.
- Assume cohesive soils are between the ground surface and the depth of 20-ft.
- Assume a surcharge load at the ground surface (q) of 500 psf.
- Assume groundwater level is at the ground surface.
- Wet unit weight is 123 pcf.
- Submerged unit weight is 61 pcf.

Calculation Procedure: From the formulas provided in Figure 5.1 bracing pressures are computed as follows:

$\mathbf{P_1}$ = 0.3 x 61 pcf x 20-ft = 366 psf

$\mathbf{P_w}$ = 62.4 pcf x 20-ft = 1,248 psf

$\mathbf{P_q}$ = 500psf x 0.5 = 250 psf

Bracing pressure at the ground surface = $\mathbf{P_q}$ = 250 psf

Bracing pressure at depths of H/4 (5-ft) = $\mathbf{P_1} + \mathbf{P_w} + \mathbf{P_q}$ = 366+62.4x5+250 = 928 psf

Bracing pressure at depth of 3H/4 (15-ft) = $\mathbf{P_1} + \mathbf{P_w} + \mathbf{P_q}$ = 366+62.4x15+250 = 1,552 psf

Bracing pressure at depth of 20-ft = $\mathbf{P_q} + \mathbf{P_w}$ = 1,248+250 = 1,498 psf

Design Example 2

Given: Determine the bracing pressures by using the formulas provided in Figure 5.2 assuming the following:

- Assume excavation is 20-ft deep.
- Assume cohesive soils are between the ground surface and the depth of 20-ft.
- Assume a surcharge load at the ground surface (q) of 500 psf.
- Assume groundwater level is at the ground surface.
- Wet unit weight is 130 pcf.
- Submerged unit weight is 65 pcf.

Calculation Procedure: From the formulas provided in Figure 5.2 lateral pressures are computed as follows:

$\mathbf{P_1}$ = 0.3 x 65 pcf x 20-ft = 390 psf (Figure 5.1)

$\mathbf{P_w}$ = 62.4 pcf x 20-ft = 1,248 psf

$\mathbf{P_q}$ = 500psf x 0.5 = 250 psf

Horizontal pressure at the ground surface = $\mathbf{P_q}$ = 250 psf

Lateral pressure at depths of H/4 (5-ft) = $\mathbf{P_1} + \mathbf{P_w} + \mathbf{P_q}$ = 488+62.4x5+250 = 1,050 psf

Lateral pressure at depth of 20-ft = $P_1+\mathbf{P_q} + \mathbf{P_w}$ = 390+250+1248= 1,888 psf

APPENDIX D
(cont'd)

Design Example 3

Given: Determine the bracing pressures by using the formulas provided in Figure 5.3 assuming the following:

- Assume depth of 20 ft.
- Cohesive soils are encountered from ground surface to a depth of 12 ft underlain by cohesionless soil to the excavation depth of 20 ft.
- Assume a surcharge load at the ground surface (q) of 500 psf.
- Assume groundwater level is at the ground surface.
- Submerged unit weight is 64 pcf (clay).
- Submerged unit weight is 41 pcf (sand).

Calculation Procedure: From the formulas provided in Figure 5.3 lateral pressure is computed as follows:

$$\mathbf{P_1} = 0.3\,\mathrm{x}\left[\frac{64(12)+41(20-12)}{20}\right]\mathrm{x}\,20 = 329\,\mathrm{psf}$$

$\mathbf{P_w}$ = 62.4 pcf x 20-ft = 1,248 psf

$\mathbf{P_q}$ = 500 psf x 0.5 = 250 psf

Horizontal pressure at the ground surface = $\mathbf{P_q}$ = 250 psf

Lateral pressure at depth of H/4 (5-ft) = $\mathbf{P_1} + \mathbf{P_w} + \mathbf{P_q}$ = 329+5x62.4+250 = 891 psf

Lateral pressure at depth of 20-ft = $\mathbf{P_1} + \mathbf{P_w} + \mathbf{P_q}$ = 329+62.4x20+250 = 1,827 psf

APPENDIX E

Piezometer Abandonment Reports

STATE OF TEXAS WELL REPORT for Tracking #352915

Owner:	**Geotest Engineering, Inc.**	Owner Well #:	**GLLP - 4 - P**
Address:	**5600 Bintliff Dr.** **Houston , TX 77036**	Grid #:	**65-23-1**
Well Location:	**2300 Federal Rd.** **Houston , TX 77547**	Latitude:	**29° 44' 15" N**
Well County:	**Harris**	Longitude:	**095° 12' 59" W**
Elevation:	**No Data**	GPS Brand Used:	**Lowrance XOG**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **12/26/2013** Completed: **12/26/2013**
Diameter of Hole:	Diameter: **5 in From Surface To 25 ft**
Drilling Method:	Other: **Auger**
Borehole Completion:	**Straight Wall**
Annular Seal Data:	1st Interval: **From 0 ft to 2 ft with 1/2 Portland (#sacks and material)** 2nd Interval: **From 2 ft to 5 ft with 1 Bentonite (#sacks and material)** 3rd Interval: **No Data** Method Used: **Poured** Cemented By: **Dempsey Gearen Jr.** Distance to Septic Field or other Concentrated Contamination: **na ft** Distance to Property Line: **na ft** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **12 ft. below land surface on 12/26/2013** Artesian flow: **No Data**
Packers:	**Homemade 5'**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**Other: none** Depth to pump bowl: **(No Data) ft**
Well Tests:	**Bailer** Yield: **.25 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **good** Depth of Strata: **1 ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Gearen Drilling** **32126 Rochen Rd.** **Waller , TX 77484**

Driller License Number:	**2836**
Licensed Well Driller Signature:	**Dempsey Gearen Jr.**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**Piezometer**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#352915**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 - 18 Dr G Clay
18 - 25 Br Sa Clay
Piezometer

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 New PVC Blank 0 - 15 Sch 40
2 New PVC Slotted 15 - 25 .010

STATE OF TEXAS PLUGGING REPORT for Tracking #93502

Owner:	Geotest Engineering, Inc.	Owner Well #:	GLLP - 4 - P
Address:	5600 Bintliff Dr. Houston , TX 77036	Grid #:	65-23-1
Well Location:	2300 Federal Rd. Houston , TX 77547	Latitude:	29° 44' 15" N
Well County:	Harris	Longitude:	095° 12' 59" W
		GPS Brand Used:	Lowrance XOG
Well Type:	Monitor		

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	Dempsey Gearen Jr.
Driller's License Number of Original Well Driller:	2836
Date Well Drilled:	12/26/2013
Well Report Tracking Number:	352915
Diameter of Borehole:	5 inches
Total Depth of Borehole:	25' feet
Date Well Plugged:	3/5/2014
Person Actually Performing Plugging Operation:	Dempsey Gearen Jr.
License Number of Plugging Operator:	2836
Plugging Method:	Tremmie pipe cement from bottom to top.
Plugging Variance #:	No Data
Casing Left Data:	1st Interval: 0 inches diameter, From 0 ft to (No Data) ft 2nd Interval: No Data 3rd Interval: No Data
Cement/Bentonite Plugs Placed in Well:	1st Interval: From 0 ft to 25 ft; Sack(s)/type of cement used: 3 Portland 2nd Interval: No Data 3rd Interval: No Data 4th Interval: No Data 5th Interval: No Data
Certification Data:	The plug installer certified that the plug installer plugged this well (or the well was plugged under the plug installer's direct supervision) and that each and all of the statements herein are true and correct. The plug installer understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	Gearen Drilling 32126 Rochen Rd. Waller , TX 77484
Plug Installer License Number:	2836

Licensed Plug Installer Signature:	**Dempsey Gearen Jr.**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#93502**) on your written request.

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STATE OF TEXAS WELL REPORT for Tracking #349220

Owner:	Geotest Engineering, Inc.	Owner Well #:	GLLP - 5 -P
Address:	5600 Bintliff Dr. Houston , TX 77036	Grid #:	65-23-1
Well Location:	Federal Rd. Houston , TX 77547	Latitude:	29° 44' 05" N
Well County:	Harris	Longitude:	095° 12' 59" W
Elevation:	No Data	GPS Brand Used:	Lowrance XOG
Type of Work:	New Well	Proposed Use:	Monitor

Drilling Date:	Started: 11/4/2013 Completed: 11/4/2013
Diameter of Hole:	Diameter: 5 in From Surface To 25 ft
Drilling Method:	Mud Rotary
Borehole Completion:	Straight Wall
Annular Seal Data:	1st Interval: From 0 ft to 2 ft with 1/2 Portland (#sacks and material) 2nd Interval: From 2 ft to 5 ft with 2 Bentonite (#sacks and material) 3rd Interval: No Data Method Used: Poured Cemented By: Dempsey Gearen Jr. Distance to Septic Field or other Concentrated Contamination: na ft Distance to Property Line: na ft Method of Verification: No Data Approved by Variance: No Data
Surface Completion:	Surface Sleeve Installed

Water Level:	Static level: 4' !0" ft. below land surface on 11/4/2013 Artesian flow: No Data
Packers:	Homemade 5'
Plugging Info:	Casing or Cement/Bentonite left in well: No Data
Type Of Pump:	Other: none Depth to pump bowl: (No Data) ft
Well Tests:	Bailer Yield: .25 GPM with (No Data) ft drawdown after (No Data) hours

Water Quality:	Type of Water: good Depth of Strata: seams ft. Chemical Analysis Made: No Did the driller knowingly penetrate any strata which contained undesirable constituents: No
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and

	correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	Gearen Drilling 32126 Rochen Rd. Waller , TX 77484
Driller License Number:	2836
Licensed Well Driller Signature:	Dempsey Gearen Jr.
Registered Driller Apprentice Signature:	No Data
Apprentice Registration Number:	No Data
Comments:	Piezometer

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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Please include the report's Tracking number (Tracking #349220) on your written request.

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DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 - 18 G & Y Sa Clay
18 - 25 G & Br Sa Clay
Piezometer

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 New PVC Blank 0 - 15 Sch. 40
2 New PVC Slotted 15 - 25 .010

STATE OF TEXAS PLUGGING REPORT for Tracking #92378

Owner:	Geotest Engineering, Inc.	Owner Well #:	GLLP - 5 - P
Address:	5600 Bintliff Dr. Houston , TX 77036	Grid #:	65-23-1
Well Location:	Federal Rd. Houston , TX 77547	Latitude:	29° 44' 05" N
Well County:	Harris	Longitude:	095° 12' 59" W
		GPS Brand Used:	Lowrance XOG

Well Type: Monitor

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	Dempsey Gearen Jr.
Driller's License Number of Original Well Driller:	2836
Date Well Drilled:	11/4/2013
Well Report Tracking Number:	349220
Diameter of Borehole:	5" inches
Total Depth of Borehole:	25' feet

Date Well Plugged:	12/26/2013
Person Actually Performing Plugging Operation:	Dempsey Gearen Jr.
License Number of Plugging Operator:	2836
Plugging Method:	Tremmie pipe cement from bottom to top.
Plugging Variance #:	No Data
Casing Left Data:	1st Interval: 0 inches diameter, From 0 ft to (No Data) ft 2nd Interval: No Data 3rd Interval: No Data
Cement/Bentonite Plugs Placed in Well:	1st Interval: From 0 ft to 25 ft; Sack(s)/type of cement used: 2 2nd Interval: No Data 3rd Interval: No Data 4th Interval: No Data 5th Interval: No Data

Certification Data: The plug installer certified that the plug installer plugged this well (or the well was plugged under the plug installer's direct supervision) and that each and all of the statements herein are true and correct. The plug installer understood that failure to complete the required items will result in the log(s) being returned for

	completion and resubmittal.
Company Information:	Gearen Drilling 32126 Rochen Rd. Waller , TX 77484
Plug Installer License Number:	2836
Licensed Plug Installer Signature:	Dempsey Gearen Jr.
Registered Plug Installer Apprentice Signature:	No Data
Apprentice Registration Number:	No Data
Plugging Method Comments:	No Data

Please include the plugging report's tracking number (Tracking #92378) on your written request.

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STATE OF TEXAS WELL REPORT for Tracking #352913

Owner:	**Geotest Engineering, Inc.**	Owner Well #:	**GLLP - 7 - P**
Address:	**5600 Bintliff Dr. Houston , TX 77036**	Grid #:	**65-23-1**
Well Location:	**2300 Federal Rd. Houston , TX 77547**	Latitude:	**29° 43' 59" N**
Well County:	**Harris**	Longitude:	**095° 13' 00" W**
Elevation:	**No Data**	GPS Brand Used:	**Lowrance XOG**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **12/26/2013** Completed: **12/26/2013**
Diameter of Hole:	Diameter: **5 in From Surface To 25 ft**
Drilling Method:	Other: **Auger**
Borehole Completion:	**Straight Wall**
Annular Seal Data:	1st Interval: **From 0 ft to 2 ft with 1/2 Portland (#sacks and material)** 2nd Interval: **From 2 ft to 5 ft with 1 Bentonite (#sacks and material)** 3rd Interval: **No Data** Method Used: **Poured** Cemented By: **Dempsey Gearen Jr.** Distance to Septic Field or other Concentrated Contamination: **na ft** Distance to Property Line: **na ft** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **6 ft. below land surface on 12/26/2013** Artesian flow: **No Data**
Packers:	**Homemade 5'**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**Other: none** Depth to pump bowl: **(No Data) ft**
Well Tests:	**Bailer** Yield: **.25 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **good** Depth of Strata: **1 ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Gearen Drilling 32126 Rochen Rd. Waller , TX 77484**

Driller License Number:	**2836**
Licensed Well Driller Signature:	**Dempsey Gearen Jr.**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**Piezometer**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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Please include the report's Tracking number (Tracking **#352913**) on your written request.

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DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 - 6 Dk G Clay
6 - 17 Rd Si Clay
17 - 25 Rd Clay
Piezometer

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 New PVC Blank 0 - 15 Sch 40
2 New PVC Slotted 15 - 25 .010

STATE OF TEXAS PLUGGING REPORT for Tracking #93503

Owner:	**Geotest Engineering, Inc.**	Owner Well #:	**GLLP - 7 - P**
Address:	**5600 Bintliff Dr. Houston , TX 77036**	Grid #:	**65-23-1**
Well Location:	**2300 Federal Rd. Houston , TX 77547**	Latitude:	**29° 43' 59" N**
Well County:	**Harris**	Longitude:	**095° 13' 00" W**
		GPS Brand Used:	**Lowrance XOG**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**Dempsey Gearen Jr.**
Driller's License Number of Original Well Driller:	**2836**
Date Well Drilled:	**12/26/2013**
Well Report Tracking Number:	**352913**
Diameter of Borehole:	**5 inches**
Total Depth of Borehole:	**25' feet**

Date Well Plugged:	**3/5/2014**
Person Actually Performing Plugging Operation:	**Dempsey Gearen Jr.**
License Number of Plugging Operator:	**2836**
Plugging Method:	**Tremmie pipe cement from bottom to top.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **0 inches diameter, From 0 ft to (No Data) ft** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite Plugs Placed in Well:	1st Interval: **From 0 ft to 25 ft; Sack(s)/type of cement used: 2 1/2 Portland** 2nd Interval: **No Data** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data:	The plug installer certified that the plug installer plugged this well (or the well was plugged under the plug installer's direct supervision) and that each and all of the statements herein are true and correct. The plug installer understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Gearen Drilling 32126 Rochen Rd. Waller , TX 77484**
Plug Installer License Number:	**2836**

Licensed Plug Installer Signature:	**Dempsey Gearen Jr.**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#93503**) on your written request.

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